# THE HAWAIIAN PLANTERS' RECORD

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*A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.*

**In This Issue:**

*Plot Replications in Field Experiments:*

The errors to which field experiments are subject are classified into various groups according to the cause of the error. Some errors tend to be compensating, others are not. The influence of plot replications in reducing the effect of errors of different sorts on yield accuracy is dealt with mathematically from the standpoint of "probable error." It is shown that there is much to be gained in accuracy by increasing within certain limits the number of plots of each treatment, provided that the nature of the soil to which the field trial is thus extended, does not, of itself, induce greater errors than the replication of plots tends to cover.

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*Lysimeter Experiments and Base Exchange:*

Chemical and physical reactions in base replacement and the results of corrective treatment are frequently confined to considerations involving surface soil phenomena. In this issue will be found a discussion of the drainage products of replacement reactions. The functions of nitrogenous fertilizers in relation to soil acidity are also discussed.

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*Sugar Cane in Relation to Drought Resistance:*

The osmotic concentration of the tissue fluids of seven sugar cane varieties was measured by determining the freezing point depression, i. e., the difference between the freezing point of the tissue fluid and that of pure water. From the results of the investigations there appears to be a correlation between the osmotic concentration and drought resistance. Uba cane is no doubt the most drought-resistant variety in Hawaii and it has the greatest freezing point depression and highest osmotic concentration of the varieties studied. Lahaina cane, which has a low freezing point depression and osmotic concentration, is without question very sensitive to drought.

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*Influence of Irrigation Water on Island Soils:*

On our plantations which are irrigated with artesian water, some fields have been reduced in fertility by salt accumulations and lowered permeability. Such soil conditions are known to follow abnormal changes in the composition of the soil solution and of certain silicate components of the clay known as zeolites. We have made a study of fields of an irrigated plantation, paying special attention to these factors, using as a basis for the investigation new developments in soil science both on the mainland and in Europe. The results of our investigation have shown the cause of low permeability of some irrigated fields and yielded methods of avoiding further recurrence of such conditions and of improving the texture of fields already reduced in permeability. A comparative study of irrigation waters with many mainland waters gave information which greatly aided in the interpretation of field conditions under study on Oahu. Mainland investigators have shown that soil permeability may be efficiently controlled through a knowledge of the composition of the irrigation water and of the soil zeolites. Our studies tend to confirm this.

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*Annual Synopsis of Mill Data:*

The 1929 Annual Synopsis of Mill Data is included in this issue. In addition to the usual tabulations and discussion of technical results, capacities of factory equipment are presented in this Synopsis. The 1929 Synopsis has been published separately as Circular 54.

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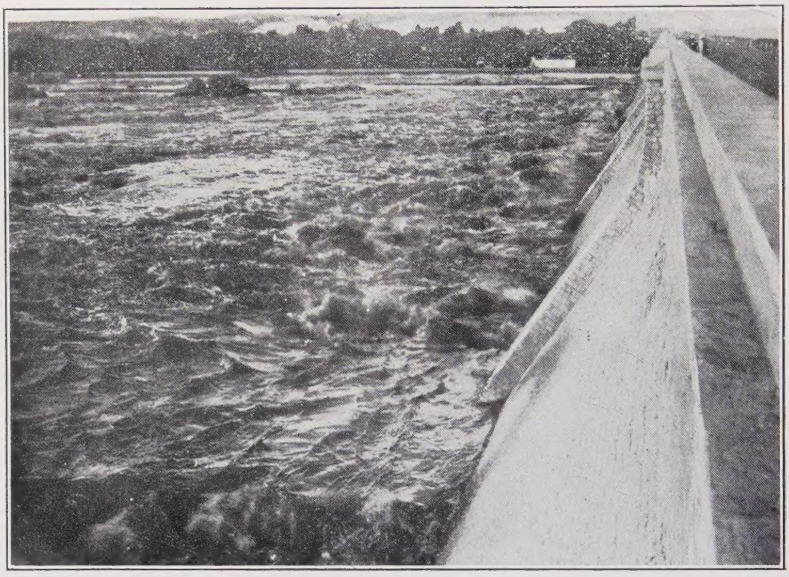
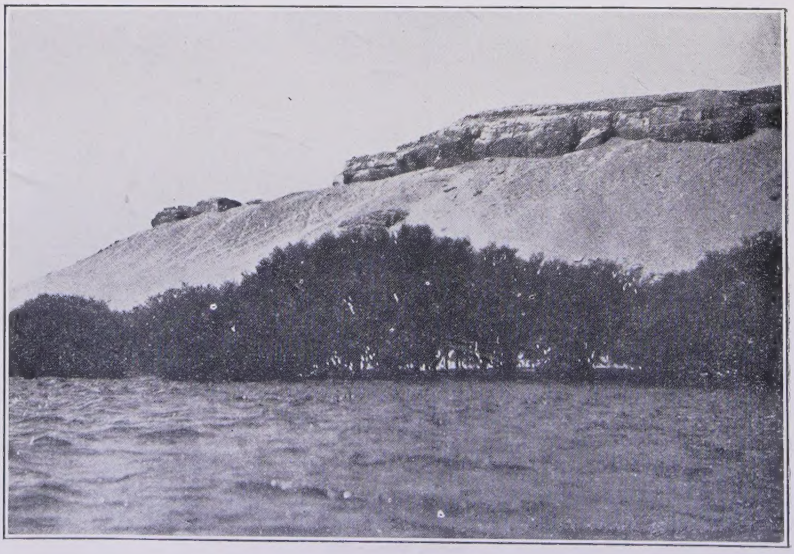
# Egyptian Views

The sugar refinery at Hawamdieh, on the banks of the Nile, that handles the output of six factories. The factories and refinery being under the same ownership, the raw sugar has a high polarization, much of it over 99, thus enabling it to enter the refining process without affination. The crop in the foreground is Milo maize.

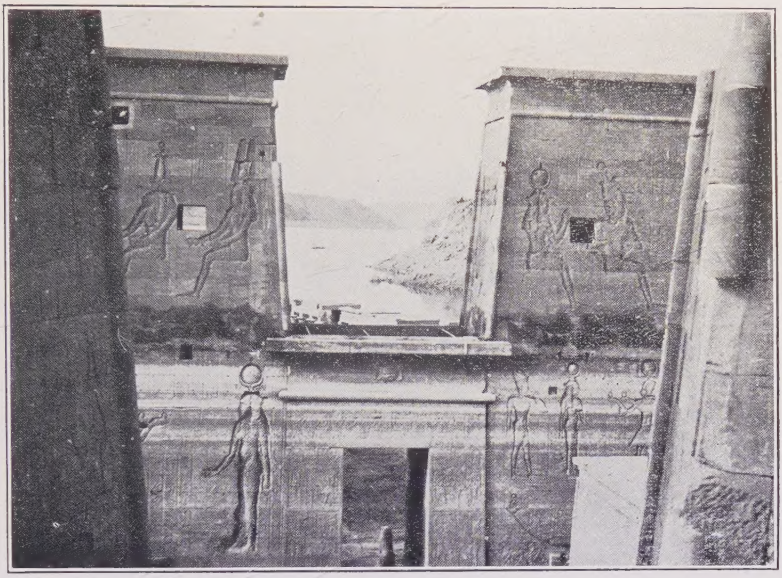
The principal cane varieties of Egypt are the P.O.J. canes of Java. On the right is P.O.J. 105, on the left P.O.J. 979, a cane which is apparently immune to the streak disease that abounds in all African cane districts.



The great dam of Assuan which causes the flood waters of the Nile to be impounded to a distance of 175 miles to the south, thereby enabling the flow of the river to be regulated in the dry season so that irrigation may be maintained.



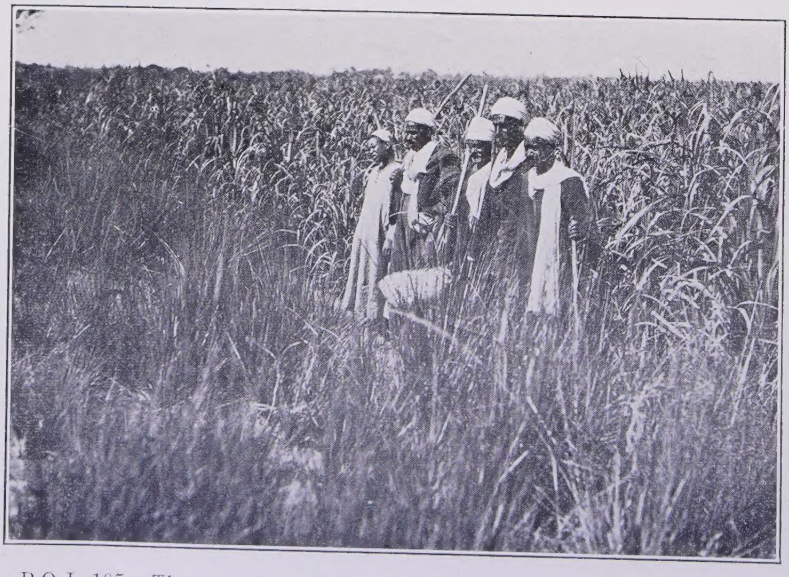
Near Assuan the valley of the Nile dwindles to nothing, and the cliffs of the desert overhang the river.



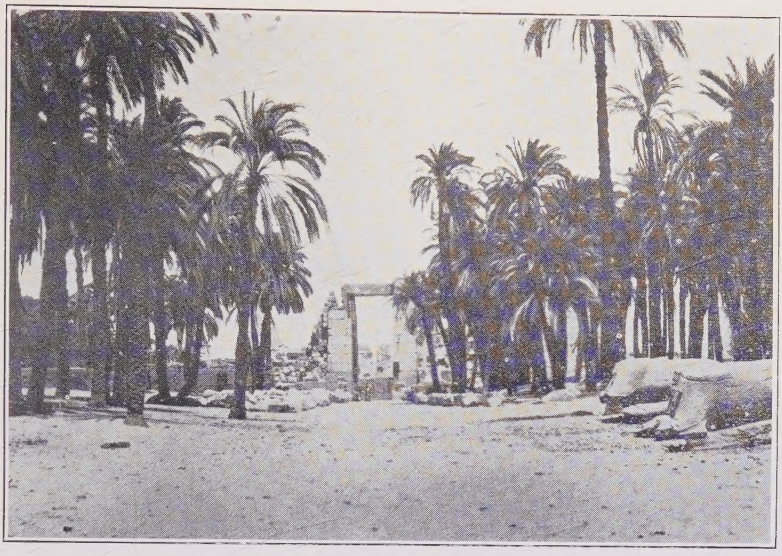
The Assuan reservoir seen through the pylons of Philae, located on an island of the river. The high-water line can be seen in the distance, and in the foreground and on the temple itself. When the dam is increased in height by 18 feet, as now planned, Philae will be completely submerged in the winter season.

Nile river boats.

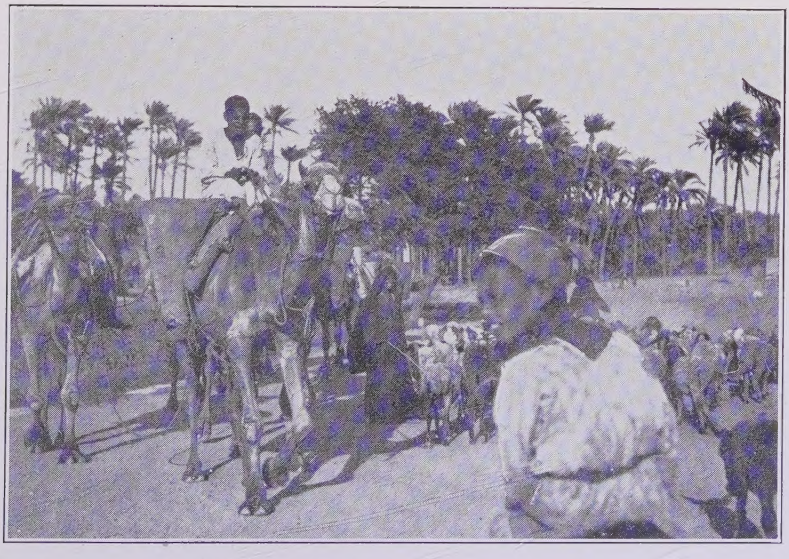
A field of sugar cane showing irrigation ditch.



P.O.J. 105. The growth in front of these field guards is a wild grass.



Relics of Egyptian architecture as seen through the date palms.

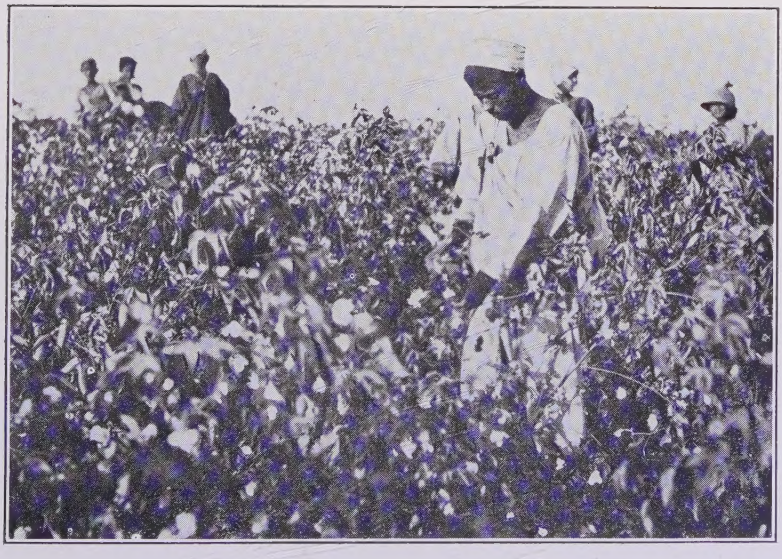


Traffic on an Egyptian roadway.

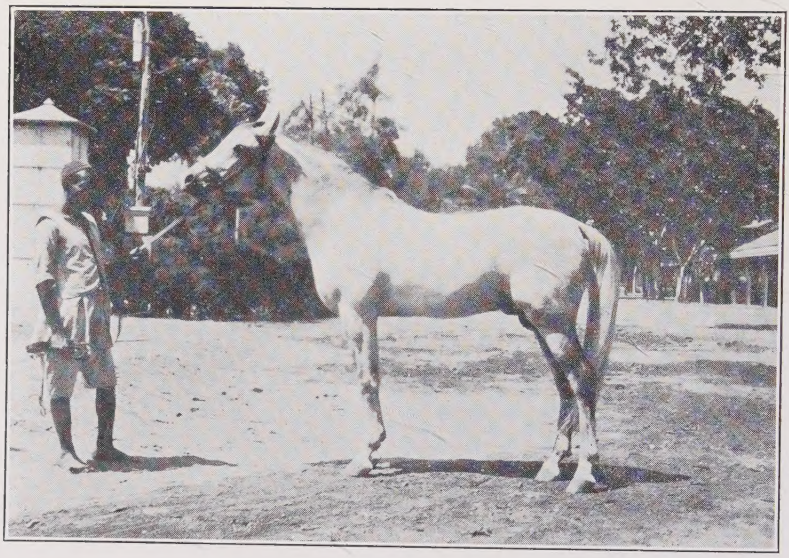
Garden about a plantation guest house at Naǵ Hamadi.

*Saccharum spontaneum* growing wild near Cairo.

Sugar cane variety plots.



Cotton, the principal crop of Egypt, has been the subject of much research on the part of the Royal Agricultural Society.



Arabian stallion from the stables of the Royal Agricultural Society.

A primitive means of lifting water still common in Egypt, although the modern pumping plant likewise exists.

Mud walls of a native village.

The temple of Karnak.

Typical view of a cane field.

# P. O. J. 36

P. O. J. 36 is being widely planted on Hawaii and Kauai, especially in areas where the rainfall is ample.

The total area planted in 1927 on the four islands amounted to only 103 acres. The 1929 plantings amounted to 2922 acres. Through the cooperation of the plantations, the plantings to be made in 1930 have been forecasted. The island of Hawaii leads with 2572 acres in prospect, followed by Kauai with 1382 acres. These data are presented in the following table:

| | Acres Planted 1927 | Acres Planted 1928 | Acres Planted 1929 | Acres to be Planted 1930 |
|---|---|---|---|---|
| HAWAII: | | | | |
| Hakalau | .... | .... | 22 | 200 |
| Hamakua Mill | 1 | 12 | 5 | 25 |
| Hawaiian Agr. | .... | .... | 16 | 130 |
| Hawi Mill | 24 | 60 | 70 | 100 |
| Hilo | .... | 1 | 9 | 75 |
| Honokaa | 37* | 171 | 187 | 225 |
| Honomu | .... | 1 | 20 | 200 |
| Hutchinson | 10 | 69 | 170 | 500 |
| Kaiwiki | .... | .... | 1 | 5 |
| Kohala | .... | .... | 5 | 90 |
| Laupahoehoe | .... | .... | 3 | 35 |
| Niulii | .... | .... | 4 | 12 |
| Olaa | .... | 2 | 34 | 325 |
| Onomea | .... | 6 | 123 | 260 |
| Paauhau | 11 | 43 | 267 | 300 |
| Pepeekeo | .... | .... | .... | 10 |
| Union Mill | .... | 1 | 8 | 80 |
| Waiakea Mill | .... | .... | .... | .... |
| Total | 83 | 366 | 944 | 2572 |
| MAUI: | | | | |
| H. C. & S. Co. | .... | .... | .... | .... |
| Kaeleku | .... | .... | 4 | 20 |
| Maui Agr. | .... | .... | .... | .... |
| Olowalu | .... | 1 | 13 | .... |
| Pioneer Mill | .... | .... | .... | .... |
| Wailuku | .... | .... | .... | 4 |
| Total | 0 | 1 | 17 | 24 |
| OAHU: | | | | |
| Ewa | .... | .... | .... | .... |
| Honolulu Pltn. | .... | 26 | 56 | 25 |
| Kahuku | .... | .... | 2 | 40 |
| Laie | .... | .... | 5 | 25 |
| Oahu Sugar Co. | .... | .... | 3 | .... |
| Waialua | .... | .... | .... | .... |
| Waianae | .... | .... | .... | .... |
| Waimanalo | .... | 31 | 375 | 250 |
| Total | 0 | 57 | 441 | 340 |
| KAUAI: | | | | |
| Grove Farm | .... | 11 | 46 | 160 |
| Hawaiian Sugar Co. | .... | .... | .... | .... |
| Kekaha | .... | 5 | .... | 25 |
| Kilauea | .... | 9 | 155 | 100 |
| Kipu | 15 | 70 | 77 | 140 |
| Koloa | .... | 102 | 236 | 100 |
| Lihue | 5 | 102 | 628 | 339 |
| Makee | .... | 84 | 274 | 453 |
| McBryde | .... | 4 | 104 | 65 |
| Waimea | .... | .... | .... | .... |
| Total | 20 | 387 | 1520 | 1382 |
| Grand Total | 103 | 811 | 2922 | 4318 |

* Planted by Pacific Sugar Mill.

# Replication of Plot Treatments in Field Experiments

By Ralph J. Borden

We have heard considerable, during recent discussions of experimental plot technique, concerning the matter of replication of treatments in our layouts for field experiments. Our attention has frequently been called to the wide range in yields which have been obtained from even those experimental plots which have had presumably identical treatment, and most of us have learned to appreciate and take cognizance of the experimental error which is included in the results of our field tests. We have come to realize that a small experimental or probable error attached to our results is synonymous with their reliability and gives us greater confidence that we can produce similar results again. This feeling of confidence is particularly evidenced when many replications of any particular plot treatment give us yields that are accompanied by low probable errors.

W. P. Alexander* has pointed out that there are certain unavoidable as well as controllable errors which create varying conditions in our test plots, and he suggests consideration of measures of proper technique and control. Messrs. Greene and Wolters* have briefly outlined some of the errors in our experimental plots which may affect results. Since the idea of plot replication is so closely tied up with this question of errors, an analysis of these errors is desirable.

*Errors of Location:* (1) Perhaps the most variable factor that we have to deal with in our test plot work, is the extreme soil heterogeneity which we encounter in our cane fields. This variation in the soil conditions may take the form of a difference in the inherent fertility, in drainage, in the water-holding capacity, in depth, exposure, or in former treatment, and it is not always evident to the eye when we "select a uniform piece of land for the experimental area." Nevertheless the difference is there, and must be considered as perhaps of major importance when we interpret our experimental results, for it may introduce an error that not only affects the results of one crop, but persists through following crops, and gives us false ideas of confidence.

(2) Plot competition may bring into our results another error which persists throughout the life of the experiment. Naquin† has given us some excellent examples of this fact, and in general, it has been given some consideration in our tests laid out on the unirrigated lands. It still is an error factor which exists in our irrigated plots and as such must have our attention in developing an improved technique for conducting field experiments.

*Errors of Preparation and Planting:* In any field test, it is essential that we have comparable stands within the individual unit plots which make up the test

* Mimeographed papers submitted to members of the Committee on Experimental Technique of the A. H. S. T. during 1929.

† *Hawaiian Planters' Record,* Vol. XXXIII, p. 421.

area. Differences in plowing, in furrowing out, in width between lines, in cleaning out the lines for planting, in seed used, are apt to result in an uneven stand or growth of cane, which may possibly introduce errors too large to be compensating ones, even though larger plots and many replications are employed in an attempt to distribute the effect of such errors.

*Errors During Progress:* After a uniform stand has been obtained in the test plots, the many operations that are yet necessary before the crop is mature are quite likely to introduce more errors. Inaccuracies in weighing out fertilizers and unevenness in their application, differences in the amount of water applied to individual plots by irrigation, variations in weed control work or in other cultural operations, as well as attacks of insect pests, disease, and rat damage, all undoubtedly have their effect on the plot yields. These are seldom as large as the errors previously mentioned, and are such that perhaps their effect can be distributed and thereby reduced by replicating the varieties of the experiment.

*Errors During Harvest:* Harvesting errors are generally due to: (1) the difficulty of an accurate separation of a tangled mass of cane stalks at the edges of the plots, (2) the failure of the cutting gang to cut stalks off uniformly at base and top, (3) inclusion of considerable trash with cane sticks. With sufficient replications of each plot treatment, it is quite possible that because of the large number of individual plants we have in each plot, these errors are of that class which are called compensating and they are not apt to affect one series of plots any more than another.

*Errors During Transportation; Errors of Weighing; Errors in Measuring Areas:* No matter how careful our experimental technique is in the field, it avails us little unless we can secure accurate weights of our product and express these in comparable and usable terms. Errors which are due to loss of cane sticks in transit from field to scales cannot be called compensating errors. The effect of inaccuracies in weighing and determining net cane weights cannot be eliminated from the plot results; they must therefore be avoided. Errors in measuring areas are avoidable and should have no place in our experimental work.

*Relative Importance:* From this analysis of the errors that get into our experimental results, it would seem that the variations in soil, the plot competition, and the incomparable stands make up for the greater part of the experimental error which accompanies our field test work. How, then, can we reduce the effect of such errors?

*Replication:* The literature on experimental technique contains many statements to the effect that replications are extremely valuable in reducing the errors that get into field experiments, and considerable data are available which seem to bear out such statements.

It is rather difficult to accept such statements, without qualifying them. In a general way, there is no question but that errors which get into our experiments during their progress and at harvest time, can be so distributed over a number of plots, that their effect upon the yields from any particular group is negligible. On the other hand, it is very difficult to conceive of replication being of value in reducing that error of location, which is due to plot competition. If an A plot

receiving 75 pounds of nitrogen is replicated adjacent to a C plot that is getting 225 pounds, in our usual series layout with watercourse plots, it is hard to believe that those plants at the ends of the 35 or 40 rows in the A plot will not reach across the watercourse and help themselves to the more abundant nitrogen supply of the C plots, thus introducing an error which cannot be affected by the usual method of replication.

Until such time as we have data to prove that we are justified in correcting the results of our test plots to allow for variations in stand thereon, we can perhaps reduce the effect of this error by using a sufficient number of replications of each treatment and making our plot areas large enough to distribute such inequalities.

It is with that *error of location* which is due to *soil variation* that this question of replication becomes paramount, and fortunately, one of our recently harvested uniformity tests, offers us figures for an intensive study.

The interesting manner in which the probable errors of a series of plots may change as the number of plots is increased, is clearly shown in the Uniformity or Blank Test harvested at Hakalau Plantation in 1929.

| | Column I | | II | | III | | IV | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plot | T.C.A. | Plot | T.C.A. | Plot | T.C.A. | Plot | T.C.A. | |
| Row A | 1 | 99.3 | 14 | 99.6 | 27 | 106.2 | 40 | 90.2 | |
| B | 2 | 98.8 | 15 | 77.5 | 28 | 94.5 | 41 | 82.7 | |
| C | 3 | 82.3 | 16 | 90.3 | 29 | 91.6 | 42 | 85.0 | |
| D | 4 | 77.8 | 17 | 83.6 | 30 | 88.5 | 43 | 90.7 | Individual plots 30'x75', contain 6 rows of cane. |
| E | 5 | 79.6 | 18 | 82.9 | 31 | 88.2 | 44 | 81.8 | |
| F | 6 | 75.9 | 19 | 86.5 | 32 | 87.5 | 45 | 87.8 | |
| G | 7 | 81.1 | 20 | 72.7 | 33 | 81.1 | 46 | 80.0 | All treatments uniform to all plots. |
| H | 8 | 78.5 | 21 | 78.4 | 34 | 78.0 | 47 | 73.1 | |
| J | 9 | 68.6 | 22 | 68.9 | 35 | 79.2 | 48 | 87.5 | |
| K | 10 | 70.7 | 23 | 67.0 | 36 | 72.7 | 49 | 75.2 | |
| L | 11 | 77.0 | 24 | 73.7 | 37 | 73.1 | 50 | 86.8 | |
| M | 12 | 82.6 | 25 | 94.2 | 38 | 88.7 | 51 | 92.5 | |

Layout of Hakalau 1929 Blank Test.

Starting with a series of four plots in Row D, we find their mean yield (Y) to be 85.1 tons of cane. To this mean is attached a probable error (PEm) of 1.929 tons, while the probable error attached to any single one (PEs) of the four plots in Row D is 3.858 tons, or 4.5 per cent of their mean yield (PEs per cent).

| Row | Plot No. | Yield | (d) Difference from Y | $d^2$ |
|---|---|---|---|---|
| D | 4 | 77.8 | 7.3 | 53.29 |
| D | 17 | 83.6 | 1.5 | 2.25 |
| D | 30 | 88.5 | 3.4 | 11.56 |
| D | 43 | 90.7 | 5.6 | 31.36 |

Mean Yield (Y) $\frac{340.6}{4} = 85.1$ $\qquad 98.46 = \Sigma d^2$

$$PEm = .6745\sqrt{\frac{\Sigma d^2}{n(n-1)}} \quad PEs = .6745\sqrt{\frac{\Sigma d^2}{n-1}} \quad PEs\ \% = \frac{PEs}{Y}$$

$$= .6745\sqrt{\frac{98.46}{4x3}} \qquad = .6745\sqrt{\frac{98.46}{3}} \qquad = \frac{3.858}{85.1}$$

$$= 1.929 \qquad = 3.858 \qquad = .045 \text{ or } 4.5\%$$

Now, if we are to provide for more replications of our plot treatments, we must extend our total experimental area to allow for same. In consequence, we may take into our test additional soil variations, thus adding new errors.

Suppose, for example, that we now double the area of plots in Row D by adding the four adjacent plots in Row E.

A study of the next table shows that in this case the increase in the experimental area that was made to provide for additional replications was responsible for distributing the experimental errors in such a way that their effect on the results are considerably reduced. The additional area did not introduce a larger error for the individual plots, and we may assume that the soil conditions in the four plots of Row E were not widely different from those in Row D.

| Row | Plot No. | Yield | d | $d^2$ |
|---|---|---|---|---|
| D | 4 | 77.8 | 6.3 | 39.69 |
| D | 17 | 83.6 | .5 | .25 |
| D | 30 | 88.5 | 4.4 | 19.36 |
| D | 43 | 90.7 | 6.6 | 43.56 |
| E | 5 | 79 6 | 4 5 | 20.25 |
| E | 18 | 82.9 | 1.2 | 1.44 |
| E | 31 | 88.2 | 4.1 | 16.81 |
| E | 44 | 81.8 | 2.3 | 5.29 |
| | | 673.1 | | |

Mean Yield (Y) $\frac{673.1}{8} = 84.1$ $\Sigma d^2 = 146.65$

PEm = 1.085 PEs = 3.084 PEs % = 3.6%

A further addition of the next twelve plots in Rows F, G and H will give us a total of 20 plots, and allow for further replications. Here again, this additional area, although it introduces soil variations which slightly increase the probable error for any one of the 20 single plots over that for the 8 single plots, gives us a more reliable test area than the four original plots would have furnished, and the error of the mean yield is as we would expect, still further reduced.

| Row | Plot No. | Yield | d | $d^2$ |
|---|---|---|---|---|
| D | 4 | 77.8 | 3.8 | 14.44 |
| D | 17 | 83.6 | 2.0 | 4.00 |
| D | 30 | 88 5 | 6 9 | 47.61 |
| D | 43 | 90.7 | 9 1 | 82.81 |
| E | 5 | 79.6 | 2.0 | 4.00 |
| E | 18 | 82.9 | 1.3 | 1.69 |
| E | 31 | 88.2 | 6.6 | 43.56 |
| E | 44 | 81.8 | .2 | .04 |
| F | 6 | 75.9 | 5.7 | 32.49 |
| F | 19 | 86 5 | 4.9 | 24.01 |
| F | 32 | 87.5 | 5 9 | 34.81 |
| F | 45 | 87.8 | 6.2 | 38.44 |
| G | 7 | 81.1 | .5 | .25 |
| G | 20 | 72.7 | 8 9 | 79.21 |
| G | 33 | 81.1 | .5 | .25 |
| G | 46 | 80.0 | 1 6 | 2.56 |
| H | 8 | 78.5 | 3.1 | 9 61 |

| Row | Plot No. | Yield | d | $d^2$ |
|---|---|---|---|---|
| H | 21 | 78.4 | 3.2 | 10.24 |
| H | 34 | 78.0 | 3.6 | 12.96 |
| H | 47 | 73.1 | 8.5 | 72.25 |

Mean Yield (Y) $\frac{1633.7}{20} = 81.6$ $\Sigma d^2 = 515.23$

PEm = .910 PEs = 3.507 PEs % = 4.2%

With this total of 20 plots, we note in the area of land thus covered, a remarkably low probable error for a single plot, and it must be concluded that these twenty plots are located upon very uniform soil and under similar soil conditions.

The addition of four more plots in Row J, gives us an example of the limit to the reduction in probable error which may be reached by replicating the plots, when a large part of this error is due to soil variation.

Summarizing, as heretofore, the yields and differences from the mean yields, for the 24 plots in Rows D, E, F, G, H, and J, we have the following:

Mean Yield (Y) $= \frac{1937.9}{24} = 80.7$ $\Sigma d^2 = 868.63$

PEm = .843 PEs = 4.141 PEs % = 5.1%

Although the probable error of the mean yield of these 24 plots is further reduced, since the total error is now distributed over more plots, the increased area which Row J has added, has brought into the experiment some wide differences in inherent fertility, as shown by the increased probable error for the single plots.

This possibility can be still more forcibly brought to our attention if we now double this area by adding to these 24 plots, the rest of the plots (in Rows K, L, M and C, B, A) of the total "Blank Test" area studied. The 48 plots will show a summarization as follows:

Mean Yield = 83.1 $\Sigma d^2 = 3722.95$

PEm = .795 PEs = 6.003 PEs % = 7.2%

All of which points to the fact that there is much to be gained in reliability of experimental results by the replication of plots, *provided* that the increased area which is thereby needed, does not by itself add a greater error with its soil variation than the replications can distribute.

# An Interpretation of Results of Lysimeter Experiments of Twenty Years Ago in the Light of Present-Day Knowledge on Base Exchange

By W. J. Hartung and F. E. Hance

The theory of base exchange founded on the work of Way, Lemberg, Van Bemmelen, Knop, Hissink, Gedroiz and Kelly and corroborated later by a great number of other investigators has made more intelligible the behavior of the various salts used and known as commercial fertilizers.

Thus, Pierre (1) working with a number of nitrogenous fertilizers made a critical study of the theory as applied not only to ammonium sulphate but to other forms of nitrogen as well. The particular subject on which Pierre desired clarification was that of induced soil acidity. He has so ably presented the view of investigators leading up to the subject of base exchange in relation to this induced soil acidity caused by certain nitrogenous fertilizers, that we may quote here in its entirety that portion of his work on the researches into the literature cited.

## THEORIES REGARDING EFFECT OF NITROGENOUS FERTILIZERS ON SOIL ACIDITY

The effect of nitrogenous and other fertilizer salts on soil reaction has been variously explained. Mayer, as is explained in detail by Kappen, was probably the first to advance a theory regarding their action. He classified fertilizers as being physiologically acid, physiologically alkaline, and physiologically neutral, depending on whether the plant absorbed the basic part, the acid part, or both parts of the salt in its nutrition. He believed that because plants utilized the potassium of potassium chloride and not the chlorine, this salt was physiologically acid, since it left a residue of hydrochloric acid in the soil. On the other hand, sodium nitrate was considered physiologically basic, since the plant utilized the nitrate and not the sodium. These ideas of Mayer were substantiated to some extent by work with solution cultures, and some field experiments also pointed to the same conclusion.

Breazeale and LeClerc, working with wheat seedlings in solution cultures, found that the use of potassium chloride and potassium sulfate tended to leave the solution acid due to the absorption of the potassium by the plant with the consequent formation of hydrochloric and sulfuric acid, respectively.

Field work with sodium nitrate and ammonium sulfate tended to substantiate this viewpoint of Mayer, for these salts were found to decrease and increase the acidity of the soil, respectively. Hall explained the effect of ammonium sulfate as follows: "The acidity of the soil where the ammonium salts have been used is due to the attack of various molds and other micro-fungi; they seize upon the nitrogen for their own nutrition and set free the acids with which the ammonia was combined."

Ruprecht and Morse in explaining their results stated that the soil absorbs the ammonia, or that there is a double decomposition between ammonium sulfate and calcium carbonate, or some other salt, thus setting free sulfuric acid.

More recent investigations have led to the development of other variously modified theories regarding the effects of various fertilizers on soil acidity, especially with respect to ammonium sulfate. Thus, Frear states as follows in regard to ammonium sulfate: "Its continuous use inevitably tends to produce pronounced acidity in the soil. The

reasons for this are not fully understood, although it is clear that it yields two acids, nitric and sulfuric, but no base, when nitrified."

As a result of the work at Rothamsted which showed that the addition of ammonium chloride and sulfate to a soil resulted in an almost immediate presence of chlorides and sulfates combined with calcium and magnesium in the drainage water, the new idea that two acids are formed from ammonium sulfate was expanded. Thus, it is described by Wheeler that double decomposition occurs in this reaction, that ammonia is absorbed by the soil, that the sulfate radical unites with the calcium and magnesium to be lost from the soil as such, thereby causing a loss of bases, and that a further loss of base occurs as a result of nitrification of the ammonia by which process the nitric acid formed unites with bases in the soil to be used up by the plants or lost through leaching as calcium or magnesium nitrates.

Ames and Schollenberger first emphasized the fact that it is because of the nitrification process alone that ammonium sulfate causes soils to become acid. They state, "When a solution of potassium or ammonium salt (except the phosphate) is brought in contact with a soil, a considerable amount of the base is rapidly removed from solution and held by the soil while the acid is left in solution, free to attack any constituents of the soil which may be soluble. Although some carbonate may be lost in this way, the soil is really no poorer in bases than it was before, because whatever has been dissolved from the soil has been compensated for by the base entering the soil. In the case of ammonium sulfate, however, the absorbed base is capable of becoming acid through the process of nitrification, and a further amount of basic material will be removed from the soil."

This view has been expanded more fully by Page who explained it according to the more recent ideas of base exchange. He emphasized the fact that nitrification is the cause of the acidity developed by ammonium sulfate and, furthermore, that it makes no difference in the acidity formed whether or not the calcium sulfate resulting from the base exchange reaction between the ammonium sulfate and the calcium complex leached out or remains in the soil. This view that nitrification rather than selective absorption of part of the fertilizer salt by the plant is the cause for the acidity developed by ammonium sulfate is further substantiated by experiments (3, 9) showing that approximately the same amounts of acidity are developed whether or not plants are growing on the soil fertilized with ammonium sulfate. Page believes that the term physiological acidity, therefore, is not strictly correct, since the action is not caused by the plant but is strictly a chemical or biological process.

Pierre, drawing on Page, then proceeds to explain the successive steps when ammonium sulfate is added to the soil:

The effect of acid forming nitrogenous fertilizers on the soil can be most easily explained, as was done by Page for ammonium sulfate, by assuming that the ammonium salt added undergoes a base exchange reaction with the absorbing complex. The absorbing complex of the soil can be represented by the formula CaX, in which Ca represents the various exchangeable bases with which the insoluble anions, X, are combined in an exchangeable form. Let it be assumed for ease of discussion that the X can only combine with one Ca. When ammonium sulfate is added to a soil the following reactions take place:

1. $(NH_4)_2\ SO_4 + CaX \longrightarrow CaSO_4 + (NH_4)_2X$
2. $(NH_4)_2\ X + O_2 \xrightarrow{\text{nitrification}} 2HNO_3 + H_2X + 2H_2O$
3. $2HNO_3 + CaX \longrightarrow Ca(NO_3)_2 + H_2X$

As a result of the reaction represented in equation 1 it is evident that no acidity is developed. Moreover, it makes little difference whether or not $CaSO_4$ is leached out of the soil, for the calcium it contains has been replaced in the exchange complex by another base, ammonium. Until nitrification, represented in equation 2, goes on no acidity is developed. As a result of nitrification it is seen that two molecules of nitric acid and

one molecule of dibasic soil acid are formed. The nitric acid may further react with another molecule of CaX, forming $CaNO_3$, in which form the nitrate may be taken up by the plant, and another molecule of $H_2X$ formed. Thus, from one molecule of ammonium sulfate two molecules of a dibasic soil acid are eventually formed. These reactions are believed to represent quite accurately what takes place when ammonium sulfate is added to a soil, for it is well known that the absorption by the soil of the ammonia from ammonium sulfate is very rapid.

In considering the manner of development of soil acidity by additions of ammonium sulfate as outlined by Pierre, the absorption of basic radicals and acid hydrogen by soil colloids, at the same time, may also be advanced; thus in balancing Pierre's equations and totalling the products on both sides of the equality sign, we have—

$$(NH_4)_2SO_4 + CaX = CaSO_4 + (NH_4)_2X$$
$$(NH_4)_2X + 4O_2 = 2HNO_3 + H_2X + 2H_2O$$
$$2HNO_3 + CaX = Ca(NO_3)_2 + H_2X$$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $(NH_4)_2SO_4$ fertilizer | + | 2CaX absorbed on soil colloid | + | $4O_2$ bacterial | = | $CaSO_4$ soil solution | + | $Ca(NO_3)_2$ soil solution | + | $2H_2X$ rep'acing CaX on soil colloid (acid) | + | $2H_2O$ |

The oxidation of the ammonium radical splits off the nitrogen which later reappears as the soluble nitrate. The hydrogen which remains is divided equally between the water formed in the reaction and as the active acid hydrogen attached to the anion X.

Thus may it be assumed that the commonly accepted "acid" constituent of the sulphate fertilizer ($SO_4$) is lost through leaching and that the acidity which later develops is found as the acid complex "$H_2X$". The adsorbed acid constituent, through the electronic attraction of its hydrogen on the soil colloid, resists leaching and perhaps functions in the soil reaction as a distinct acid body. In order to remain adsorbed on the soil colloid the concentration of hydrogen as ion must be higher in the surrounding media than any basic or other replaceable ions. This supposition may be met by accepting the very probable fact that the acid complex ionizes thus—

$$H_2X \rightleftharpoons 2H^{+} + X^{--}.$$

Hence the acidity which is finally developed may be traced in logical steps from an unlooked-for source in the ammonium or basic constituent of the sulfate nitrogen fertilizer.

We may visualize that portion of the soil capable of base exchange as Kerr (2) pictures zeolites, viz: crystalline bodies having space lattices, open in structure. The hypothetical structure shown below is intended to convey the idea of exchange presented by the above three reactions. No claim is made that the soil complex exists as indicated.

Net result, calcium entering soil solution, oxidation of ammonium in which all of the nitrogen enters soil solution as nitrate, half the hydrogen forms water and the other half becomes acid hydrogen in the complex $H_2X$.

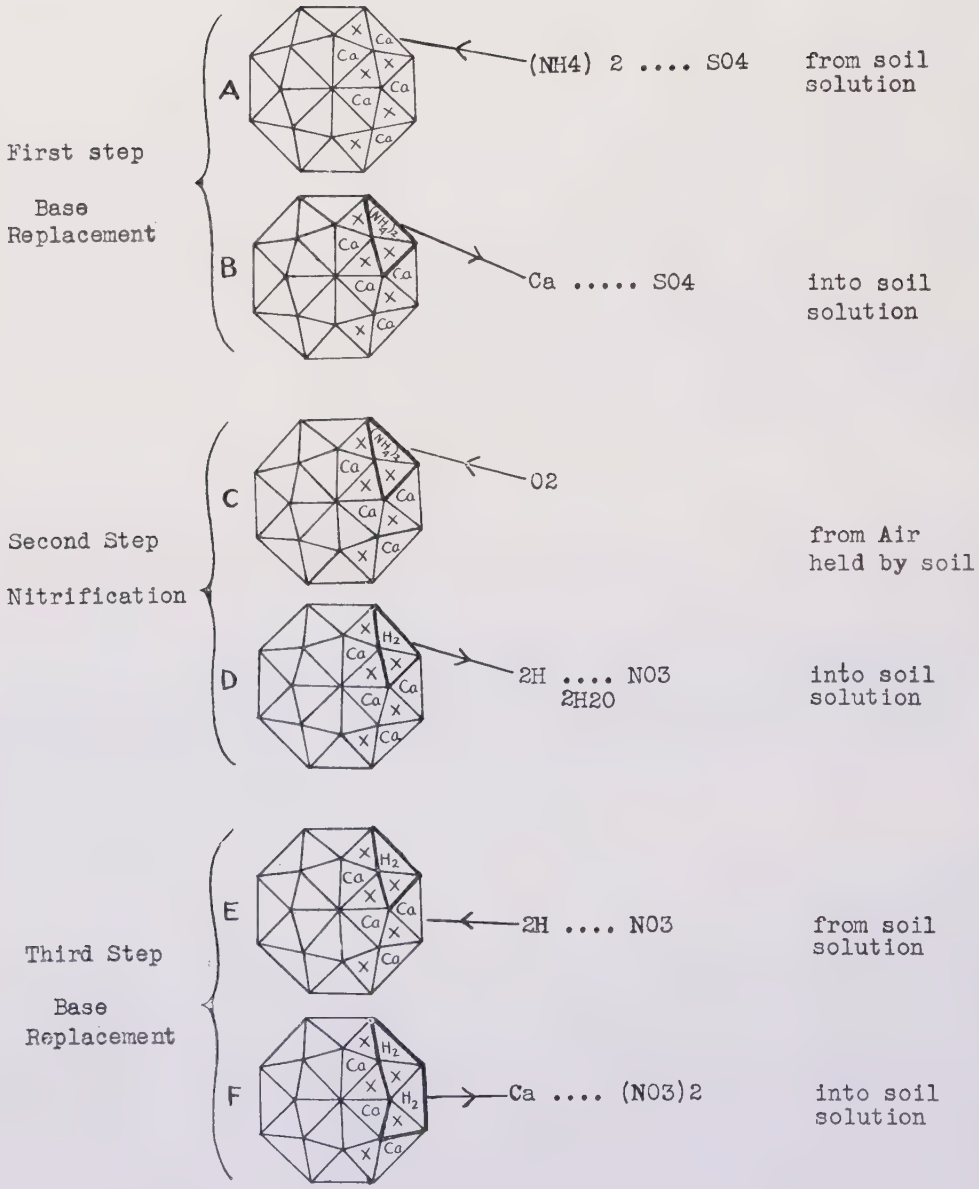

First step
Base Replacement
A
B
(NH4) 2 .... S04
from soil solution
Ca ..... S04
into soil solution
Second Step
Nitrification
C
D
02
from Air held by soil
2H .... N03
2H20
into soil solution
Third Step
Base Replacement
E
F
2H .... N03
from soil solution
Ca .... (N03)2
into soil solution

Fig. 1

## Lysimeter Experiments

*Bulletins 19, 8 and 37 of the Experiment Station of the Hawaiian Sugar Planters' Association*

In the first series of the work in Bulletin 19 (3), Experiment Station soil was used in testing the relative rate of nitrification of tankage, fish scrap, hoof meal, sulphate of ammonia and dried blood. Tests with nitrate of soda and with unfertilized soil were carried on concurrently. Fresh water was used in the irrigation or leaching operation. The time intervening between each successive irrigation was 7 days. The initial quantity of water applied was 20 liters per lysimeter; the next three irrigations were at the rate of 10 liters each and beginning with irrigation No. 5, 15 liters of water per lysimeter became the regular dosage. Only determinations of nitric nitrogen and lime were made on the leachate.

Data presented bearing on the loss of nitrate nitrogen and lime through leaching show that although the loss of nitric nitrogen is less in the sulphate of ammonia than in the nitrate of soda lysimeter, nevertheless sulphate of ammonia is responsible for decidedly heavier losses of lime. The writers have taken the privilege of drawing on the material of tables on pages 11 and 18 of this lysimeter work and adding to it somewhat, thus bringing out the points that bear directly on base replacement.

**Table from Page 11, Bulletin 19**

NITRIC NITROGEN IN DRAINAGE

**Grams**

| Irrigation | No. 7 Check | No. 9 Nitrate Soda | No. 10 Sul. Ammonia | A Diff. (9-7) | B Diff. (10-7) |
|---|---|---|---|---|---|
| 1 | ..... | ..... | ..... | ..... | ..... |
| 2 | .88872 | 5.11190 | 1.00852 | 4.22318 | .11980 |
| 3 | .40040 | 7.88018 | .37140 | 7.47978 | —.02900 |
| 4 | .09621 | 2.33056 | .25401 | 2.23435 | .15780 |
| 5 | .08983 | .42241 | .44622 | .33258 | .35639 |
| 6 | .08109 | .12400 | 2.15917 | .04291 | 2.07808 |
| 7 | .10051 | .12006 | 1.94687 | .01955 | 1.84636 |
| 8 | .09843 | .13075 | 1.80652 | .03232 | 1.70809 |
| 9 | .12138 | .15700 | 1.91406 | .03562 | 1.79268 |
| 10 | .12613 | .14940 | 1.72121 | .02327 | 1.59508 |
| 11 | .19569 | .19387 | 1.11168 | —.00182 | .91599 |
| 12 | .11540 | .19142 | .70231 | .07602 | .58691 |
| 13 | .13257 | .17006 | .53900 | .03749 | .40643 |
| 14 | .12651 | .18737 | .37161 | .06086 | .24510 |
| 15 | .15699 | .18624 | .33129 | .02925 | .17430 |
| 16 | .11147 | .13683 | .24867 | .02536 | .13720 |
| 17 | .12495 | .13369 | .17469 | .00874 | .04974 |
| 18 | .08257 | .08235 | .12032 | —.00022 | .03775 |
| 19 | .08221 | .09947 | .11771 | .01726 | .03550 |
| 20 | .07491 | .12264 | .11298 | .04773 | .03807 |
| 21 | .07056 | .08581 | .12952 | .01525 | .05896 |
| Totals ..... | 3.27653 | 18.01601 | 15.58776 | 14.73948 | 12.31123 |

**Explanation**

Lysimeter No. 7 containing 188 pounds of Station soil only.

Lysimeter No. 9 containing 188 pounds of Station soil to the 50-pound surface layer, of which 16.3 g. of nitrogen in the form of nitrate of soda had been added.

Lysimeter No. 10 containing 188 pounds of Station soil to the 50-pound surface layer, of which 16.3 g. of nitrogen in the form of ammonium sulphate had been added.

Table from Page 18, Bulletin 19

LIME CONTAINED IN DRAINAGE

Grams

| Irrigation | No. 7 Check | No. 9 Nitrate Soda | No. 10 Sul. Ammonia | C Diff. (9-7) | D Diff. (10-7) |
|---|---|---|---|---|---|
| 1 | ..... | ..... | ..... | ..... | ..... |
| 2 | 6.05170 | 11.04840 | 6.05115 | 4.99670 | —.00055 |
| 3 | 2.99585 | 9.99277 | 3.98652 | 6.99692 | .99067 |
| 4 | 1.55658 | 3.10107 | 3.71574 | 1.54449 | 2.15916 |
| 5 | .76217 | .94605 | 2.62856 | .18388 | 1.86639 |
| 6 | .49484 | .46046 | 2.67746 | —.03438 | 2.18262 |
| 7 | .41693 | .38272 | 2.55937 | —.03421 | 2.14244 |
| 8 | .30000 | .27456 | 2.29059 | —.02544 | 1.99059 |
| 9 | .30940 | .28500 | 2.33906 | —.02440 | 2.02966 |
| 10 | .24612 | .27272 | 1.77927 | .02660 | 1.53315 |
| 11 | .23707 | .31446 | 1.36762 | .07739 | 1.13055 |
| 12 | .23026 | .27346 | 1.00584 | .04320 | .77558 |
| 13 | .24877 | .23306 | .86900 | —.01571 | .62023 |
| 14 | .23870 | .34991 | .71368 | .11121 | .47498 |
| 15 | .35956 | .48327 | .76734 | .12371 | .40778 |
| 16 | .27125 | .20996 | .66518 | —.06129 | .39393 |
| 17 | .27710 | .20527 | .55361 | —.07183 | .27651 |
| 18 | .22213 | .11340 | .40108 | —.10873 | .17895 |
| 19 | .24403 | .15236 | .40964 | —.09167 | .16561 |
| 20 | .25286 | .17071 | .37391 | —.08215 | .12105 |
| 21 | .30240 | .16903 | .44188 | —.13337 | .13948 |
| Totals ..... | 16.01772 | 29.43864 | 35.59650 | 13.42092 | 19.57878 |

Eckart (3) does not attempt in this bulletin to give a reason for these excess amounts of lime in the leachate of the fertilized over the unfertilized check. He states: "The fact that for each pound of nitrogen added to this particular soil, 1.2 pounds of lime were rendered soluble where sulphate ammonia was used and .82 pound of lime where nitrate of soda was applied shows that the idea which is prevalent in these Islands to the effect that nitrate is the lime robber, comparatively speaking, is unfounded."

In an earlier work of the Experiment Station, H. S. P. A., (4) lysimeters, fertilized and unfertilized, were irrigated with water containing 200 grains per gallon of common salt in simulation of plantation practice where salt-bearing well water is utilized. The same soil with fresh water irrigation yielded in twenty-two irrigations but 24.80 grams of lime, whereas the salt water irrigation resulted in a leachate containing 139.15 grams of lime. Both lysimeters had had applications of fertilizer as follows: nitrogen, 20 grams from ammonium sulphate; $K_2O$, 10 grams from potash sulphate; and $P_2O_5$, 10 grams from double super. The lysimeter having no manurial treatment irrigated with saline water of same strength, yielded 120.22 grams of lime. It is quite apparent that sodium chloride in the water has acted as the replacing agent and (Na) has taken the place of (Ca) in the soil complex. In addition the ammonia radical has behaved similarly, viz., replacing more calcium and later on nitrification resulting in still greater quantities of lime going into the leachate.

Eckart is quite near to the present day interpretation when he states, "When a solution of various salts is allowed to remain in contact with a soil for any length of time, the latter exchanges certain of its elements for those in the salt solution."

In the lysimeter experiments conducted by Peck (5) on "upland soil," with nitrogen added all as sulphate of ammonia, again as in the previous work a very heavy lime content was found in the leachate of those lysimeters which had an application of nitrogen in this form alone. Peck in his discussion touches on replacement thus: "This increase may have been due to a substitution by the ammonia of calcium in the soil, the formation of soluble calcium sulphate and its recovery in the leachings, or the increased nitric oxide formed during nitrification combining with the lime in the soil the soluble amount, or again it may be the combined effect of both reactions."

Fig. 2 graphically presents tabulated reworked data of columns A and C. The plotted values indicate quite convincingly the replacement of the soil calcium by the sodium contained in the nitrate of soda. Thus the nitrate nitrogen in the drainage was without question largely calcium nitrate.

In Fig. 3, where nitrogen was added to the soil in the form of ammonium sulphate, the curves reveal the base exchange step as well as subsequent nitrification and a second replacement. Thus we note that although no nitric nitrogen appears in the first three irrigations, calcium is found in the drainage in relatively large quantities. When nitrification is well under way we find that the two lines (B and D) all but coincide. Unfortunately, no ($SO_3$) determinations were made on the leachate yet we may visualize the base exchange (Step 1) illustrated in drawings above as having taken place at once with the calcium making its appearance in the subsequent drainage waters very probably in the sulphate form. And that on nitrification of the ammonia (Step 2) there follows immediately a further replacement (Step 3) resulting in the presence of calcium nitrate in the drainage as indicated by the close correlation of the lime and nitric nitrogen lines.

Fig. 4 illustrates the nitric nitrogen and lime behavior where ammonium sulphate had been applied to upland soil, Peck (5). The curves represent the excess of nitric nitrogen and lime removed through irrigations with distilled water, lysimeter No. 5. The method followed by Peck was similar to that followed by Eckart. However, instead of tubs, cylinders 2 feet in height and 8 inches in diameter were employed. Irrigations were made every 14 days instead of every 7 days using distilled water as against fresh. Each lysimeter had but 25 pounds of soil and .57 gram of added nitrogen. Working with these small quantities the curves are almost a duplication of those illustrated in Fig. 3. This soil shows a relatively low lime content (aspartic acid method) but is very high in total magnesia. Whereas the soil used in lysimeter No. 17 nitric nitrogen and lime, curves of which appear in Fig. 5, had been previously limed and yielded a high aspartic acid lime content in comparison thus:

ASPARTIC ACID METHOD

| | Upland Soil | Lowland Soil |
|---|---|---|
| Lime (CaO) | 0.035 per cent | 0.290 per cent |

**Soluble in Strong Hydrochloric Acid (O. A. C. Method)**

| | | |
|---|---|---|
| Lime (CaO) | .85 per cent | .84 per cent |
| Magnesia (MgO) | 2.47 per cent | .84 per cent |

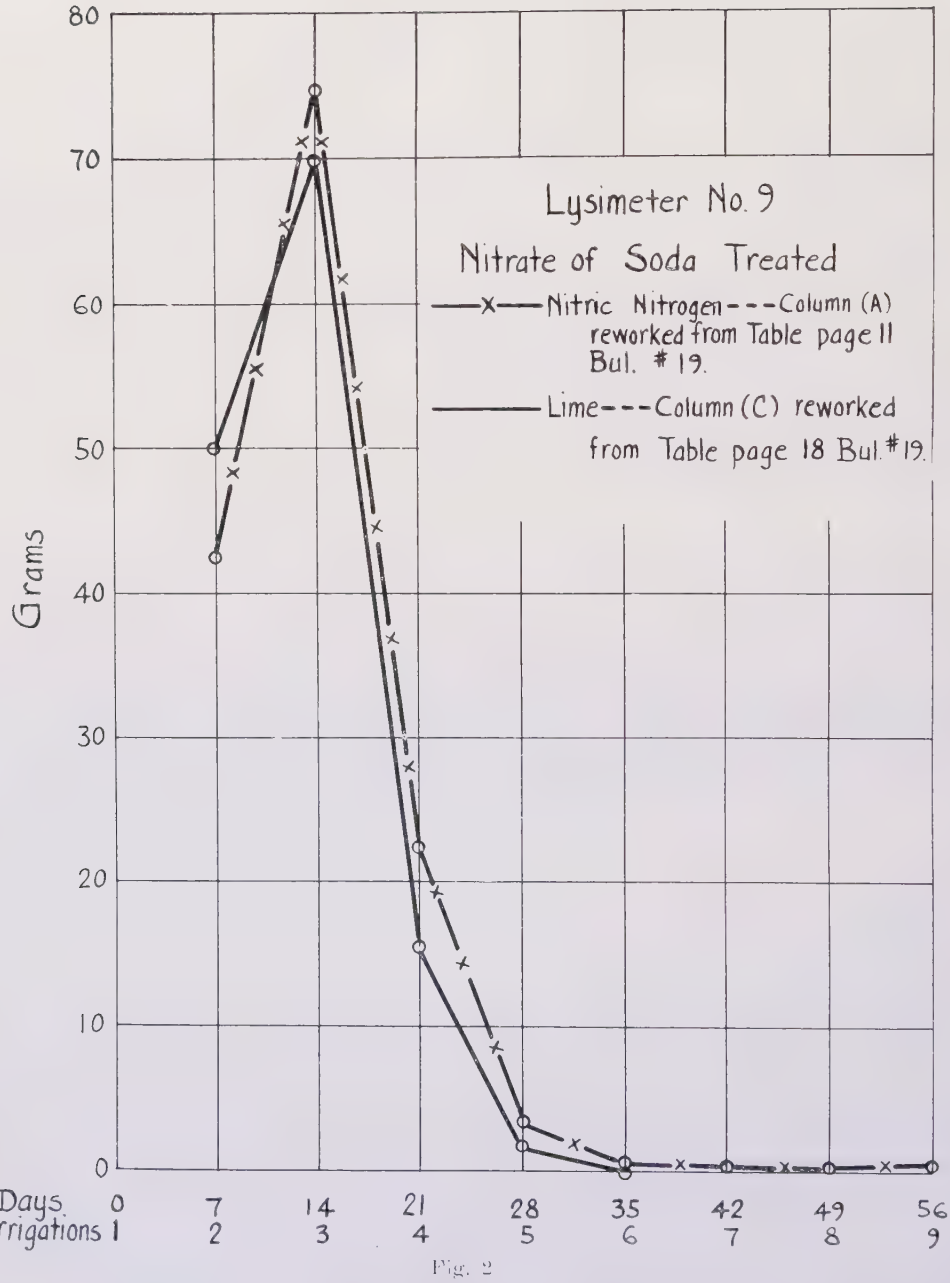

Lysimeter No. 9
Nitrate of Soda Treated
—x— Nitric Nitrogen - - - Column (A) reworked from Table page 11 Bul. # 19.
——— Lime - - - Column (C) reworked from Table page 18 Bul. # 19.
Grams
80
70
60
50
40
30
20
10
0
Days 0 7 14 21 28 35 42 49 56
Irrigations 1 2 3 4 5 6 7 8 9

Fig. 2

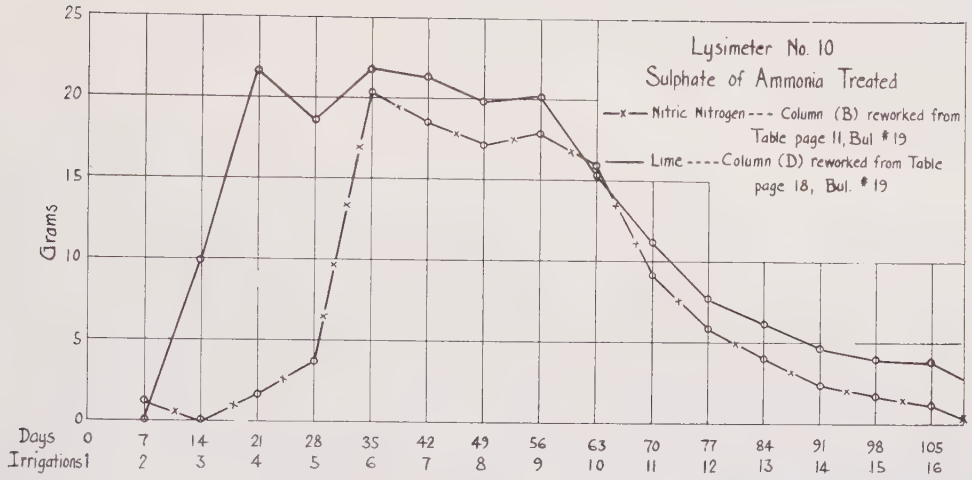

Lysimeter No. 10
Sulphate of Ammonia Treated
Nitric Nitrogen --- Column (B) reworked from Table page 11, Bul # 19
Lime ---- Column (D) reworked from Table page 18, Bul. # 19
Grams
Days
Irrigations

Fig. 3

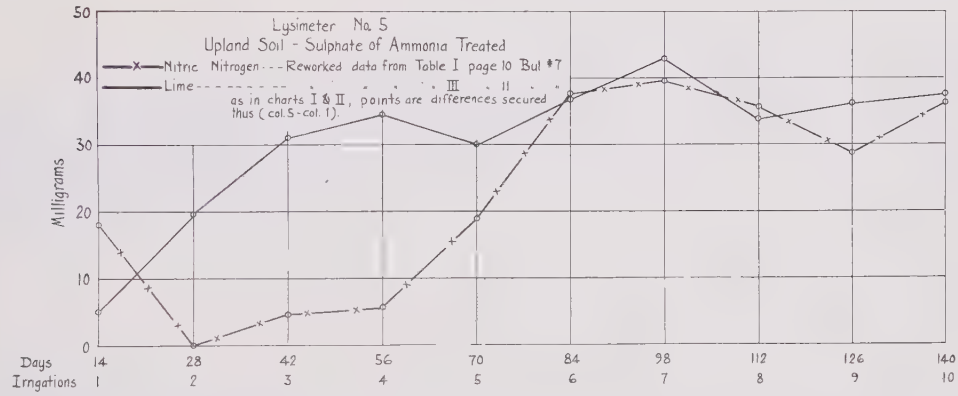

Lysimeter No. 5
Upland Soil - Sulphate of Ammonia Treated
Nitric Nitrogen --- Reworked data from Table I page 10 Bul # 7
Lime ---- " " " " III " 11 " "
as in charts I & II, points are differences secured thus (col. 5 - col. 1).
Milligrams
Days
Irrigations

Fig. 4

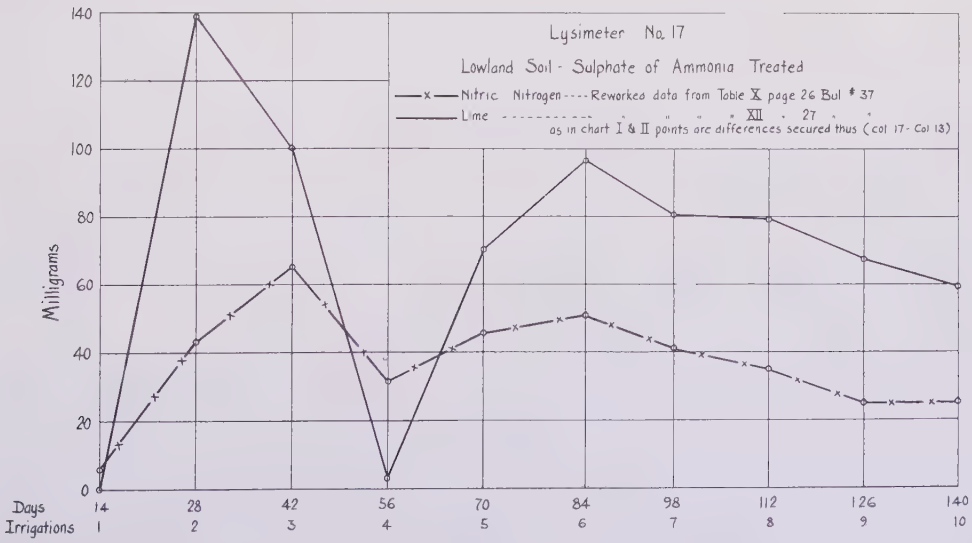

Lysimeter No. 17
Lowland Soil - Sulphate of Ammonia Treated
Nitric Nitrogen ---- Reworked data from Table X page 26 Bul # 37
Lime ---- " " " " XII " 27 " "
as in chart I & II points are differences secured thus (col 17 - Col 13)
Milligrams
Days
Irrigations

Fig. 5

The lime as indicated by aspartic acid method is in all probability replaceable. We may therefore attribute the irregularity in the lime curve, Fig. 5, to this high replaceable lime. Nitrification, too, was rather rapid, which would account for the excessive lime in the leachate when added to that resulting from Step 1 in replacement. There is one lime determination, the fourth irrigation, much at variance, for which apparently no explanation exists. All other points, with the exception mentioned, when connected up present curves that indicate a close relationship existing between the lime and the nitric nitrogen.

We have confined our interpretation to the lime and nitric nitrogen figures only. The bulletins referred to contain data on potash in these lysimeter drainage waters which likewise present a very interesting study from the standpoint of base exchange. For example, a table on page 25 of Bulletin 19, comparing the action of different forms of lime, shows that where gypsum is used in the soil the drainage from the lysimeter contains 80 per cent more $K_2O$ than is found in the drainage of the check lysimeter.

## Conclusion

Although these data, appearing in bulletins cited, are insufficient proof that the reactions are those of base replacement, yet they do furnish very striking evidence that just such changes have occurred.

It is evident that a great deal of value may be gleaned through study of old lysimeter data; also that still more may be added to our knowledge of fertilizers by more lysimeter experiments, well planned and carefully conducted. Lysimeters offer a ready method in base exchange and soil solution studies. It is quite apparent that to provide for thoroughness, treatments should be in replications of three or more; that there be tests on the degree of acidity or alkalinity of the soil and all drainage waters; that determinations be made of other cations and anions, of soil colloids, and of the replaceables, on the soil and soil solution under investigation. This is particularly important in fertilizer studies. A great many of our newer forms of nitrogen could be tested very speedily in this manner and the information secured would have a practical value as well as an academic value.

The rearrangement of and deduction made from Eckart's and Peck's data at this late date for the purpose of illustrating quantitative replacement phenomenon occasion the authors considerable satisfaction in finding such painstaking accuracy in detail and technique in investigational work of a previous decade.

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# The Properties of the Tissue Fluids of Sugar Cane in Their Possible Relation to Drought Resistance

By J. Arthur Harris* and H. Atherton Lee†

## Introduction

The factors which determine the differences in the capacities of varieties of agricultural plants to resist drought are so complex that they can be differentiated only by critical scientific experimentation of the most diverse kinds. The importance of the problem, both from the standpoint of scientific theory and agricultural practice, is so great that it justifies every effort to disentangle this complex of factors, and to express them in terms of quantitative science.

Breeding for drought resistance must remain a purely empirical undertaking until the exact physiological and structural factors determining drought resistance are actually ascertained.

The purpose of this paper is to present a limited series of determinations made on the tissue fluids of seven varieties of cane grown under comparable conditions on the grounds of the Experiment Station of the Hawaiian Sugar Planters' Association in Honolulu in the summer of 1924, and to suggest the possible bearing of the results thus obtained on the problem of drought resistance in cane.

The theory underlying the interpretation of these results rests largely on studies of the vegetation of climatically diverse regions. These must be briefly reviewed as a background for the conclusions drawn from these preliminary studies of sugar cane.

From the standpoint of chemical and physiological theory it might be assumed that the capacity of the plant to develop under conditions of aridity or high salinity may be in some degree dependent on the osmotic pressure or osmotic concentration of its tissue fluids. It is to be assumed that the magnitude of this concentration is a factor of importance in determining the capacity of the plant for the withdrawal of water from the soil. The pioneer studies of Drabble and Drabble (1) in English habitats and of Fitting (2) in the extreme conditions of the North African deserts tend to support this view.

The studies by Drabble and Drabble and by Fitting were carried out by methods not capable of yielding the most precise results. They have been followed by measurements made by more exact physical means in a widely diversified series of plant habitants. Measurements of the osmotic concentration of the tissue fluids of native plants have been made by the freezing point method in the Arizona deserts (3), in the highly saline deserts of the Lake Bonneville Basin (4), in the coastal deserts of Jamaica (5), and in the Mangrove swamp (6).

* Head of Department of Botany, University of Minnesota.

† Formerly of the Experiment Station, H. S. P. A.; now with Philippine Sugar Association.

These studies, which have been in part reverified by studies on the native vegetation of the more arid portions of Oahu, T. H., have shown that the plants of arid and saline regions are characterized by a higher osmotic concentration of their tissue fluids than those of the moister habitats of the eastern United States (7), where electrical conductivity of the sap has also been investigated (8), and of the Montane Rain Forest of Jamaica (9).

The results of these studies have been confirmed by (as yet unpublished) investigations in the subtropical jungles of southern Florida, and by preliminary studies in the rain-forests of Oahu.

The results of these investigations, which have been reinforced by parallel studies on the osmotic concentration (10) and on the electrical conductivity (11) of the tissue fluids of epiphytic plants, i. e., of the so-called "air plants," fully justify the conclusion that the capacity of the plant for withdrawing water from arid or saline soil is in some degree dependent on the concentration of its tissue fluids. They early led to the conclusion that physicochemical measurements on the plant tissue fluids should play an important role in plant geographical investigations (12).

If this conclusion be valid, it should be found that the osmotic concentration of the tissue fluids of parasitic plants is higher than that of the hosts. This is the conclusion reached by Senn (13) and by wholly independent studies of our own on the osmotic concentration of rain-forest (14) and desert Loranthaceae (15) parasitic on various host plants, and on the electrical conductivity of the tissue fluids of desert mistletoes (16). Further evidence in the same direction may be furnished by our demonstration (17), confirmed by the work of other authors, that the osmotic concentration of the leaf tissue fluids increases with the height of leaf insertion in trees.

That these relationships between parasite and host do not obtain universally is shown by the fact that in the dodder, *Cuscuta,* the osmotic concentration and electrical conductivity of the parasite may be lower than that of the host plant (18).

Since the plant species which constitute the natural vegetation of regions which differ greatly in the aridity or salinity of the soil have been shown to differ in the physicochemical properties of their tissue fluids, it would seem quite reasonable to assume that the properties of the tissue fluids of crop plants may be of importance in determining the possibility of their growth and productiveness under the varying soil and atmospheric conditions of different regions. These studies have, therefore, been extended to a number of agricultural plants.

Harris and Popenoe considered the osmotic concentration of the tissue fluids of the avocado in their possible relation to frost resistance (19).

The most extensive studies have been those based on Egyptian and Upland cotton as grown under irrigation in the arid regions of the United States. In these studies it has been shown that Pima Egyptian cotton has a higher osmotic concentration, specific electrical conductivity and hydrogen-ion concentration than either Meade or Acala Upland cotton (20). This differentiation of the Egyptian and Upland type seems to be general, since it has been found to hold for a number

of varieties of the Egyptian type recently introduced from Egypt into the United States (21).

The differentiation of these two types is not limited to the total solutes of the sap or to the concentration of all electrolytes, but is found to obtain specifically for chlorides (22) and for sulphates (23). The absorption of these anions has been shown to be differential (24). Furthermore the rate of accumulation of chlorides in the Egyptian types seems to be more rapid than in the Upland type. There are evidences for definite behavior of certain of these tissue fluid properties in hybridization.

## Preliminary Results for Sugar Cane

The osmotic concentration of the tissue fluids is most readily and accurately measured by determining the freezing point depression, i. e., the difference between the freezing point of the tissue fluid and that of pure water. Osmotic concentration is then calculated by G. N. Lewis' formula:

$$P = 12.06 \triangle - .021 \triangle^2$$

where $P$ is the osmotic concentration in atmospheres and $\triangle$ is the freezing point depression of the sap, corrected for the amount of ice separating because of undercooling (25).

Freezing point depression was determined on saps extracted by pressure after antecedent freezing in an ice-salt mixture to increase the permeability of the tissues as has been shown to be necessary by Dixon and Atkins (26) and by ourselves (27) and others.

Samples were taken from plants of seven varieties of cane grown on the Honolulu grounds of the Experiment Station of the Hawaiian Sugar Planters' Association. All plants were under conditions as nearly comparable as could be secured. Leaf samples were taken from the third, fourth and fifth leaves from the tip of the stalk. Samples of stalks were taken from the lowest nodes in order to secure as nearly comparable materials as possible.

The cultures on the Experiment Station grounds were very limited in extent and the plants were required for other purposes. Samples were, therefore, restricted to a very few stalks. As a result of this necessary limitation, the constants show the irregularities which are generally found when measurements are based on samples of limited size. This difficulty can be overcome only by carrying out the investigations on a larger scale.

The varieties employed and the dates of collection are given in the accompanying tables.

Table I shows the freezing point depression in degrees centigrade of the leaf tissue fluids of the seven varieties of cane as determined on six different dates. For the purpose of bringing out clearly the relative values of osmotic concentration in the different varieties, the names of the varieties have been given under each date in the order of the freezing point depression, from the highest to the lowest value. Table II gives the same results calculated in terms of atmospheres of osmotic pressure, $P$.

In examining these results one must be impressed by the fact that the leaf tissue fluids of Uba are characterized by higher osmotic concentration than those of any other of the seven varieties considered. While the differences between varieties are in all cases small, Uba stands at the head of the list in each of the six series of determinations made. The other varieties show considerable irregularities, as might be expected when determinations are based upon a very limited amount of material as was necessary in the present case.

If we consider the average values of the constants for the six determinations we have the following results:

| Variety of Cane | Freezing Point Depression | Osmotic Concentration |
|---|---|---|
| Uba | 0.823 | 9.91 |
| Badila | 0.701 | 8.44 |
| Yellow Caledonia | 0.693 | 8.35 |
| H-109 | 0.682 | 8.21 |
| D-1135 | 0.679 | 8.18 |
| Lahaina | 0.649 | 7.82 |
| Yellow Tip | 0.646 | 7.78 |

The difference between the average constant for Uba and the highest of the other varieties is 0.122°, or 1.47 atmospheres. The difference between the highest (Badila) and the lowest (Yellow Tip) constant for varieties other than Uba is only 0.055°, or 0.66 atmosphere.

The freezing point depressions of the juice from the basal nodes of the stem are arranged in order in Table III. The results are expressed in terms of atmospheres pressure in Table IV.

TABLE I

Freezing Point Depression of the Leaf Tissue Fluids of Seven Varieties of Cane Arranged in the Order of Their Magnitudes

| Aug. 29 | Sept. 5 | Sept. 16 | Sept. 17 | Sept. 19 | Oct. 1 |
|---|---|---|---|---|---|
| Uba<br>.984 | Uba<br>.855 | Uba<br>.826 | Uba<br>.763 | Uba<br>.746 | Uba<br>.765 |
| Lahaina<br>.752 | Badila<br>.753 | Yellow Caledonia<br>.757 | H 109<br>.735 | Badila<br>.676 | H 109<br>.719 |
| Badila<br>.749 | D 1135<br>.727 | D 1135<br>.717 | D 1135<br>.714 | H 109<br>.670 | Lahaina<br>.712 |
| Yellow Caledonia<br>.723 | Yellow Caledonia<br>.696 | H 109<br>.708 | Yellow Caledonia<br>.693 | D 1135<br>.640 | Badila<br>.688 |
| Yellow Tip<br>.685 | Yellow Tip<br>.669 | Badila<br>.686 | Badila<br>.654 | Yellow Tip<br>.611 | Yellow Caledonia<br>.681 |
| D 1135<br>.688 | Lahaina<br>.608 | Lahaina<br>.667 | Yellow Tip<br>.639 | Yellow Caledonia<br>.608 | Yellow Tip<br>.626 |
| H 109<br>.659 | H 109<br>.598 | Yellow Tip<br>.647 | Lahaina<br>.604 | Lahaina<br>.553 | D 1135<br>.609 |

TABLE II

Calculated Osmotic Concentration in Atmospheres of the Leaf Tissue Fluids of Seven Varieties of Cane Arranged in the Order of Their Magnitudes

| Aug. 29 | Sept. 5 | Sept. 16 | Sept. 17 | Sept. 19 | Oct. 1 |
|---|---|---|---|---|---|
| Uba | Uba | Uba | Uba | Uba | Uba |
| 11.850 | 10.290 | 9.936 | 9.195 | 8.991 | 9.213 |
| Lahaina | Badila | Yellow Caledonia | H 109 | Badila | H 109 |
| 9.057 | 9.069 | 9.117 | 8.852 | 8.143 | 8.660 |
| Badila | D 1135 | D 1135 | D 1135 | H 109 | Lahaina |
| 9.021 | 8.756 | 8.642 | 8.600 | 8.065 | 8.576 |
| Yellow Caledonia | Yellow Caledonia | H 109 | Yellow Caledonia | D 1135 | Badila |
| 8.708 | 8.383 | 8.528 | 8.353 | 7.710 | 8.281 |
| Yellow Tip | Yellow Tip | Badila | Badila | Yellow Tip | Yellow Caledonia |
| 8.251 | 8.065 | 8.269 | 7.872 | 7.355 | 8.203 |
| D 1135 | Lahaina | Lahaina | Yellow Tip | Yellow Caledonia | Yellow Tip |
| 8.046 | 7.324 | 8.034 | 7.691 | 7.330 | 7.541 |
| H 109 | H 109 | Yellow Tip | Lahaina | Lahaina | D 1135 |
| 7.938 | 7.198 | 7.800 | 7.282 | 6.657 | 7.337 |

TABLE III

Freezing Point Depression of the Stalk Tissue Fluids of Seven Varieties of Cane Arranged in the Order of Their Magnitudes

| Aug. 29 | Sept. 5 | Sept. 16 | Sept. 17 | Sept. 19 | Oct. 1 |
|---|---|---|---|---|---|
| Uba | Uba | Uba | Uba | Uba | Uba |
| 1.422 | 1.532 | 1.642 | 1.603 | 1.606 | 1.611 |
| Lahaina | Yellow Caledonia | Yellow Caledonia | Yellow Caledonia | Badila | H 109 |
| 1.403 | 1.520 | 1.571 | 1.392 | 1.573 | 1.393 |
| Yellow Caledonia | Lahaina | Badila | D 1135 | Yellow Caledonia | D 1135 |
| 1.374 | 1.379 | 1.470 | 1.250 | 1.520 | 1.351 |
| H 109 | H 109 | Yellow Tip | H 109 | H 109 | Yellow Caledonia |
| 1.208 | 1.227 | 1.298 | 1.221 | 1.337 | 1.342 |
| D 1135 | Badila | D 1135 | Badila | Lahaina | Lahaina |
| 1.162 | 1.221 | 1.274 | 1.216 | 1.139 | 1.310 |
| Yellow Tip | Yellow Tip | H 109 | Yellow Tip | Yellow Tip | Badila |
| 1.102 | 1.144 | 1.159 | 1.184 | 1.083 | 1.227 |
| Badila | D 1135 | Lahaina | Lahaina | D 1135 | Yellow Tip |
| 1.098 | 1.075 | 1.101 | 1.135 | .878 | 1.191 |

TABLE IV

Calculated Osmotic Concentration in Atmospheres of the Stalk Tissue Fluids of Seven Varieties of Cane Arranged in the Order of Their Magnitudes

| Aug. 29 | Sept. 5 | Sept. 16 | Sept. 17 | Sept. 19 | Oct. 1 |
|---|---|---|---|---|---|
| Uba | Uba | Uba | Uba | Uba | Uba |
| 17.10 | 18.42 | 19.75 | 19.28 | 19.31 | 19.37 |
| Lahaina | Yellow Caledonia | Yellow Caledonia | Yellow Caledonia | Badila | H 109 |
| 16.88 | 18.27 | 18.89 | 16.74 | 18.92 | 16.76 |
| Yellow Caledonia | Lahaina | Badila | D 1135 | Yellow Caledonia | D 1135 |
| 16.53 | 16.59 | 17.68 | 15.05 | 18.29 | 16.25 |
| H 109 | H 109 | Yellow Tip | H 109 | H 109 | Yellow Caledonia |
| 14.54 | 14.76 | 15.61 | 14.70 | 16.08 | 16.14 |
| D 1135 | Badila | D 1135 | Badila | Lahaina | Lahaina |
| 13.98 | 14.68 | 15.32 | 14.63 | 13.71 | 15.76 |
| Yellow Tip | Yellow Tip | H 109 | Yellow Tip | Yellow Tip | Badila |
| 13.27 | 13.77 | 13.94 | 14.24 | 13.04 | 14.76 |
| Badila | D 1135 | Lahaina | Lahaina | D 1135 | Yellow Tip |
| 13.21 | 12.94 | 13.25 | 13.65 | 10.56 | 14.34 |

Again we note that in every series of determinations the highest osmotic concentrations are found in Uba.

The averages for the six determinations available for each variety are:

| Variety of Cane | Freezing Point Depression | Osmotic Concentration |
|---|---|---|
| Uba | 1.569 | 18.87 |
| Yellow Caledonia | 1.453 | 17.48 |
| Badila | 1.301 | 15.65 |
| H-109 | 1.257 | 15.13 |
| Lahaina | 1.245 | 14.97 |
| Yellow Tip | 1.167 | 14.05 |
| D 1135 | 1.165 | 14.02 |

In both series of averages (for leaves and stems) Uba stands at the head of the list, and is followed by Yellow Caledonia and Badila, but the order of these two latter is reversed in the case of the determinations on leaves and stems. In both cases H 109 occupies the fourth position. Lahaina, D 1135 and Yellow Tip show the lowest values in the determinations on leaves and stems.

*Judged by purely physiological standards* the conclusions to be drawn from these meager data would be that Uba should be the most drought resistant of the seven varieties considered, while H 109 should occupy an intermediate position between Uba, Yellow Caledonia and Badila on the one hand and Lahaina, Yellow Tip and D 1135 on the other, the three latter together with H 109 presumably representing the least drought resistant varieties of the seven considered.

## Discussion of Results

The foregoing conclusions were based entirely upon a study of the tissue fluids. Comparing these results with practical experience in the growing of sugar cane, one is led to the conclusion that osmotic pressure of either the leaf or cane stalk juices is correlated to a certain degree with drought resistance.

The Uba variety is without doubt the most drought-resistant cane grown in the Hawaiian Islands and, as the tables of results show, has the greatest freezing point depression and highest osmotic concentration of any of the other varieties by a considerable margin. Moreover, the Lahaina variety, which has a low freezing point depression and osmotic concentration, is without question a sensitive variety to drought. On the other hand, D 1135 and Yellow Tip are canes that grow normally under unirrigated conditions and have drought resistance. W. P. Naquin, from his observations in Hamakua, places Uba first in drought resistance, D 1135 second, and Yellow Caledonia third, followed by Yellow Tip and H 109. "Growth measurements," he says, "made during several dry spells in this district showed that these canes ran about as above. I believe that Mr. Jennings found at Kohala that Yellow Tip was far less resistant to dry weather than D 1135, although Yellow Tip kept green very much longer than D 1135. The growth, however, was checked very much more rapidly with the Tip."

Too much stress must not be laid on these results until confirmed by more extensive series of determinations and more adequate tests of relative drought re-

sistance under the conditions of the growing of sugar cane. It is a question for further endeavor to attempt to utilize osmotic concentration determinations in actual practice to predetermine the drought resistance of a new variety. The writers feel that these preliminary attempts of such prediction should at least be put on record for the use of future investigators.

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# The Chemical and Physical Properties of Ewa Plantation Soils as Influenced by Irrigation With Artesian Water, With Special Reference to Drainage

By W. T. McGeorge

*One phase of the irrigation problem at Ewa Plantation is that it has been confronted in several of its fields with badly puddled and poorly drained soil types, a high water table and salt accumulation. In view of this the plantation management was interested to learn, on the basis of new developments in soil science, the present status of their soils and what will be the ultimate effect of continuously irrigating with saline waters. The work presented in this paper was planned at a conference of Messrs. George F. Renton, W. P. Alexander and J. D. Bond, of the plantation staff, and the writer, and is presented in this form in the Record because its application is general for Island conditions. The writer is indebted to these members of the plantation staff for their hearty cooperation in this work.*

One of the important problems affecting the fertility on irrigated plantations is the presence of salt in the irrigation water and its accumulation in the soil. In the past we have devoted considerable time and effort to this problem in an attempt to increase our knowledge and understanding of its many phases. In two previous articles (1) the writer has dealt at some length upon the presence of salt in our irrigated fields, and some physiological effects of excess salt accumulation upon cane growth. The investigations of our predecessors, Maxwell, Eckart, Peck and Burgess, have also been reviewed and presented in abstract. In their work, as well as our own, there is conclusive evidence of a salt accumulation in a number of Island areas which has exceeded the limit of tolerance of some cane varieties. These studies have demonstrated the outstanding property of H 109 to resist the toxic effect of high concentrations of salt in the soil solution. While a knowledge of salt accumulation and its physiological effect upon cane growth is of interest and value, the problem is incomplete without some knowledge of the effect upon soil properties, such as the present and ultimate changes in mechanical condition and chemical composition.

With few exceptions the soil fertility of agricultural districts has received many serious setbacks in the United States and in foreign countries where rainfall is insufficient and must be supplemented by artificial irrigation. Many of our own fields have been under irrigation for forty years or more. What then is the present status of these soils as compared with irrigated areas in other countries, and can we offer an estimate of what the ultimate effect of saline irrigation water will be on our own fields? Or better still, can we offer suggestions which will help us to avoid the difficulties others have encountered? To date we have had few really

serious alkali soil problems. In the United States, as well as in several foreign countries, many of the outstanding leaders in soil science have been occupied with this problem and some remarkable progress has been made. As a result of their investigations, we now have a rather definite understanding of the chemical and physical changes taking place in soils where it is necessary to resort to irrigation to meet the water requirement of the crop.

The most fertile soils are, in the main, well satisfied, chemically, with calcium. It has been known for seventy-five years or more that soils possess the property of fixing bases such as calcium, magnesium, sodium, potassium. Our present knowledge of the nature of this fixation and an appreciation of its value has aided greatly in identifying the cause and nature of soil peculiarities. The theory of this phenomenon has been previously dealt with in some detail in the *Record*. Suffice it to say here that the so-called fixed bases are subject to replacement by other bases added in fertilizer or irrigation water, and that if best fertility is to be maintained an effort should be made to retain calcium as the predominating fixed base. Such highly hydrolytic bases as magnesium or sodium, if they reach certain proportions, will seriously injure or completely destroy the fertility of the soil. We then have a soil state which is classified as one of the alkali types.

As already stated, toxic concentrations of salt have been found in some of our plantation soils. Both Peck and Burgess obtained evidence of sodium carbonate in Island soils, but unfortunately, they were not equipped at that time with our present methods and apparatus to determine its degree. Alkali soils were classified then as of one of two types, namely, white alkali or black alkali. The former included all types containing salts other than sodium carbonate, and the latter included sodium carbonate which, due to its solvent action toward organic matter, gave a black soil solution. We no longer look upon alkali soils as being unrelated types but rather as soils in different degrees of sodium or magnesium saturation with or without an accumulation of salines. In fact, so-called black alkali soils may contain no sodium carbonate, as shown by de'Sigmond (2) and by Breazeale and McGeorge (3), but they may have an alkalinity entirely derived from the hydrolysis of "fixed" sodium. Then, too, as shown by de'Sigmond (2), black alkali soils may be practically free of soluble salts. It is just a short step, therefore, under certain cultural practices, from a white alkali to a black alkali type if sodium is the predominating base, and this type of soil is very difficult to reclaim.

de'Sigmond (2) gives three factors which are responsible for the change from non-injurious saline types to undesirable alkali types, as follows:

1. Arid or semi-arid climate.
2. Impervious subsoil.
3. Peculiar hydrological circumstances enabling a superabundance of water in the soil intersected by dry periods.

Kelley (4) emphasizes the (a) use of saline irrigation water and (b) high water table from excessive irrigation as being major causes of alkali formation and he points out that waters not excessively saline have often caused undesirable alkaline conditions. Hilgard regarded an arid climate as related to alkali soil

formation but de'Sigmond points out that even in very arid climates soils are fertile if they are permeable.

The writer believes it to be a very good policy to consider the alkali problem from two rather closely defined angles, namely, (a) an accumulation of excessive quantities of salt to produce a soil solution of toxic concentration, and (b) a soil condition of relative impermeability caused by the well-known property of alkali (hydroxyl ion) to convert clay into a highly dispersed state which closes the pore spaces of the soil and seriously limits aeration and permeability. It is in the second class that the more serious troubles arise. Many saline irrigation waters may be entirely free of any injurious effects upon the soil or plant and, if permeability is maintained and water judiciously applied, soil fertility will be permanent. Such waters are mainly high calcium waters. On the other hand, high sodium or magnesium waters usually result in undesirable soil conditions.

A description of the process by which irrigation waters may injure or improve soils may be of interest at this point. The compounds which impart to soils the property of base fixation and base exchange* are known as zeolites and believed to be complex silicates of colloidal dimensions. They are sometimes referred to in soils as the exchange complex. When a salt solution or irrigation water of basic composition different from that of the fixed soil bases is brought in contact with the exchange complex of the soil, there will be an exchange of the predominant base of the solution for that of the exchange complex of the soil. That is, if the zeolite base of the soil is in greatest part calcium and the soil is irrigated with a high sodium water, the calcium will be replaced in whole or in part and leached away in the drainage while its place in the exchange complex will be taken by sodium. The exchange reaction is practically instantaneous. The relative affinity of the exchange complex for the different bases stands in the following order: $Ca > Mg > K > Na$, while the relative degree of clay dispersion, as well as hydration of respective ions, stands in the following and opposite order: $Na > K > Mg > Ca$. It may be seen from the above why high calcium soils are normal soils and vice versa from the lower affinity for sodium, why this type of soil is abnormal and only formed when a relatively large excess of sodium is present in the soil solution.

## Conditions at Ewa and Outline of Problem

Rainfall at Ewa Plantation Company averages about 20 inches per annum. Pump waters only are used for irrigation. In some fields a high water table has interfered with cane ripening, and in these fields tile drains have been installed to lower this water table. The soils include heavy adobe clays, friable clay loams and a number of "coral" types. The salt accumulation varies from practically nil to toxic concentrations. For investigation the problem was divided into four phases as follows:

1. The present composition of the soil zeolites at Ewa and the nature and amount of salt accumulation.

* The fixed or replaceable bases will be referred to as zeolite bases throughout this paper.

2. The tile drainage system and the changes taking place in the soil as a result of their installation.

3. The quality of Ewa irrigation waters as compared with a number of mainland waters of known value.

4. Remedial measures for the correction and removal of undesirable accumulations of magnesium and sodium.

## Zeolites in Ewa Soils

As an initial step a number of fields were selected and soil samples obtained, some being sampled to a depth of only one foot and others to three or four feet. All samples were taken with a soil auger and three to six borings per sample, depending upon the size of the area. The following is a description of the soils:

1. Field 19B—red silty clay loam, no coral, good drainage, fertile field.

2. Field 26B—blackish clay, drainage only fair, surface layer caked. This field is irrigated with a water high in magnesium.

3. Field 17A—red silty clay loam, good field and good drainage.

4. Field 3D—this field had recently been tiled. A blackish clay; many spots in the field were poorly drained. This sample taken near drain well where cane growth was excellent and drainage fair; salt efflorescence in some areas.

4b. Subsoil to 4, second foot, slightly heavier than 4.

5. A bad spot in field 3D where drainage is poor.

6. Fair spot in field 3D.

7. Bad spot in field 3D.

9. Field 21A—red silty clay loam, good drainage, no coral.

10. Field 21A—same as 9, except taken in area where there is considerable coral.

Samples 11, 12, 13 and 14 were taken from good and bad spots in field 11, which has been tile drained for five years, originally had high water table.

11. Heavy clay, poorly drained, cane making poor growth.

11b. Second foot to 11.

11c. Third foot to 11.

12. Same type as 11 but better drained and cane making good growth.

12b. Second foot to 12.

12c. Third foot to 12.

13. Same type as 11, practically no germination (ratoons) in this area, drainage poor and some salt efflorescence.

13b. Second foot to 13.

13c. Third foot to 13.

14. Same type as 11, good area, good drainage, good cane growth.

14b. Second foot to 14.

14c. Third foot to 14.

15. Same type as 11, field 14.

15b. Second foot to 15.

15c. Third foot to 15.

16. Field C, heavy clay soil, highly dispersed, considerable salt accumulation, cane germinates very poorly or not at all, tile drains recently installed.

16b. Second foot to 16.

16c. Third foot to 16.

17. Field C, same type as 16, sample taken near drainage well where drainage is good and cane growth fair.

17b. Second foot to 17.

17c. Third foot to 17.

18. Red clay loam taken in camp near field 11, not cultivated.

19. Field A, red clay loam, poorly drained area.

19b. Second foot to 19.

19c. Third foot to 19.

20. Field A, poorly drained area, same type as 19.

20b. Second foot to 20.

20c. Third foot to 20.

20d. Fourth foot to 20, this sample represents a hardpan at the four-foot level.

21. Field A, well drained area, same type as 19.

21b. Second foot to 21.

21c. Third foot to 21.

Samples 22 to 26, inclusive, were taken in the peninsular fields of Oahu Sugar Company as representative of the black adobe type with coral rock.

22. A good area, coral.

23. A poor area, no coral.

24. A good area, coral.

25. A poor area, no coral.

26. A good area, coral.

The complex which goes to make up a soil is often divided into active and passive constituents. The latter includes the practically inert materials which serve as a soil skeleton functioning largely as a mechanical support for the plant, and by disintegration and decomposition to form the active constituents. The former include the available forms of plant food, the soluble constituents of the soil solution and the insoluble constituents which are fixed by the soil in forms that will react chemically with bases present in the soil solution, that is, the soil zeolites. Our examination of the preceding soils has covered only the active constituents.

Most of the soil samples were too badly puddled to permit obtaining the soil solution by displacement. For this reason the relative soluble salt content was determined by analyzing a 1:5 water extract and calculating back to a basis of a soil solution of 20 per cent moisture content, which is about optimum for these soils. While this does not represent the true soil solution, the results are comparative. The zeolite bases were determined by replacement with both barium chloride and ammonium chloride. The results of these analyses are given in

Tables I and II. The zeolite bases are expressed as per cent in dry soil, ratio of each base to the sum of the bases, and as milliequivalents* per 100 grams of soil.

Before attempting to interpret the data in these tables it is of interest to present some similar analyses of soils from other sources and of known properties. The following are taken from data obtained by Kelley (5) from a number of soils from California, Arizona, Nevada, Utah and Idaho, which he has separated into poor and intermediate alkali soils and into good soils:

| | Per Cent Dry Soil | Per Cent of Total Bases |
|---|---|---|
| Bad alkali soils— | | |
| Calcium | .0 –.079 | 0–14 |
| Magnesium | .0 –.113 | 0–31 |
| Sodium | .082–.842 | 50–97 |
| Intermediate alkali soils— | | |
| Calcium | .158–.261 | 36–52 |
| Magnesium | .0 –.098 | 0–30 |
| Sodium | .094–.153 | 22–32 |
| Good soils— | | |
| Calcium | .151–.594 | 53–80 |
| Magnesium | .062–.162 | 16–38 |
| Sodium | .005–.047 | 1–9 |

Normal soils of the temperate zone usually contain 80-90 per cent calcium with small amounts of magnesium, sodium and potassium.

Fields 19B, 17A, 21A and 14 are all good fields and, as compared with mainland soils, would be classed as good soils, or at least better than intermediate saline types. In other words, there is no evidence that saline irrigation or the use of nitrate of soda has caused any rapid progressive soil changes in well-drained fields.

All the rest of the fields examined were selected for abnormal types. In Field 26B there is an abnormally high percentage of zeolite magnesium and this has greatly affected the mechanical texture of the soil. The clay is highly dispersed and this has materially retarded drainage. Also, the soil "cakes" considerably on drying.

Field A, located in the Apokaa Section of the plantation, has given some trouble to the irrigators on account of the difference in the rate at which different sections of the field take water. Samples of soil were taken from two poorly drained areas and from one good area. In two cases the first, second and third foot were sampled. In the third case the fourth foot was also sampled as a clay hardpan was found below the third foot in the poorly drained areas, and this latter is represented by 20d. The principal difference between the poor and well-drained areas is in the acidity (replaceable hydrogen) in the subsoils of the former. On the whole, though, there is a higher percentage of zeolite calcium and lower sodium in the good area. The excess of sodium, magnesium and hydrogen (acidity) zeolites in the hardpan is significant and also explains the low permeability of poor areas in this field.

* On this basis each base is directly comparable with another or with hydrogen in the proportion by weight at which they are capable of replacing each other.

TABLE I

Composition of Soil Solution When the Soil Contains 20 Per Cent Moisture—Results Given in Parts per Million Soil Solution

| Field | Sample | Sample Depth | Soluble Solids | Calcium Ca | Magnesium Mg | Sodium Na | Potassium K | Sulphate $SO_4$ | Chlorine Cl | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 19B | 1 | 0–1 | 4652 | 144 | 185 | 595 | 510 | 102 | 1066 | Good drainage |
| 17A | 3 | 0–1 | 6389 | 260 | 412 | 1108 | 488 | 417 | 2424 | " |
| 21A | 9 | 0–1 | 4334 | 154 | 308 | 931 | 224 | 416 | 1417 | " |
| 21A | 10 | 0–1 | 8304 | 432 | 400 | 1170 | 843 | 484 | 2698 | " |
| 14 | 15a | 0–1 | 3089 | 240 | 272 | 700 | 143 | 105 | 634 | Fair drainage |
| 14 | 15b | 1–2 | 3518 | 276 | 269 | 1264 | 184 | 325 | 955 | " |
| 14 | 15c | 2–3 | 3688 | 285 | 294 | 1246 | 205 | 424 | 1060 | " |
| 26B | 2 | 0–1 | 4581 | 192 | 271 | 947 | 294 | 112 | 988 | " |
| A | 19a | 0–1 | 5392 | 404 | 204 | 952 | 68 | 2252 | 996 | " |
| A | 19b | 1–2 | 5060 | 316 | 188 | 908 | 64 | 2200 | 952 | " |
| A | 19c | 2–3 | 4428 | 212 | 156 | 888 | 52 | 1960 | 868 | " |
| A | 20a | 0–1 | 3276 | 148 | 92 | 760 | 52 | 1244 | 548 | " |
| A | 20b | 1–2 | 3944 | 212 | 124 | 824 | 60 | 1884 | 592 | " |
| A | 20c | 2–3 | 4052 | 168 | 120 | 912 | 188 | 1968 | 784 | " |
| A | 20d | 3–4 | 6732 | 108 | 68 | 2056 | 248 | 4164 | 1712 | " |
| A | 21a | 0–1 | 2448 | 64 | 12 | 524 | 92 | 316 | 420 | Good drainage |
| A | 21b | 1–2 | 1984 | 64 | 16 | 504 | 92 | 412 | 356 | " |
| A | 21c | 2–3 | 2164 | 44 | 8 | 572 | 60 | 1796 | 464 | " |
| 3D | 4 | 0–1 | 7361 | 158 | 211 | 1063 | 280 | 856 | 1284 | Fair drainage |
| 3D | 4b | 1–2 | 7961 | 256 | 348 | 1478 | 586 | 1712 | 2524 | " |
| 3D | 5 | 0–1 | 11513 | 640 | 676 | 1711 | 700 | 1185 | 4139 | Poor drainage |
| 3D | 6 | 0–1 | 10380 | 447 | 604 | 1791 | 640 | 1060 | 3180 | " |
| 3D | 7 | 0–1 | 10256 | 521 | 614 | 1736 | 642 | 1276 | 3064 | " |
| 11 | 11a | 0–1 | 5372 | 255 | 400 | 1010 | 400 | 746 | 1577 | " |
| 11 | 11b | 1–2 | 8043 | 389 | 619 | 1470 | 206 | 1702 | 2128 | " |
| 11 | 11c | 2–3 | 7983 | 409 | 598 | 1518 | 215 | 1689 | 2449 | " |
| 11 | 12a | 0–1 | 3541 | 173 | 187 | 600 | 263 | 105 | 591 | Fair drainage |
| 11 | 12b | 1–2 | 2930 | 135 | 108 | 811 | 144 | 169 | 467 | " |
| 11 | 12c | 2–3 | 3574 | 180 | 210 | 910 | 131 | 319 | 934 | " |
| 11 | 13a | 0–1 | 11003 | 724 | 723 | 846 | 143 | 1163 | 3470 | Poor drainage |
| 11 | 13b | 1–2 | 11812 | 794 | 699 | 1172 | 171 | 2674 | 3680 | " |
| 11 | 13c | 2–3 | 12824 | 691 | 587 | 2702 | 131 | 2582 | 4088 | " |
| 11 | 14a | 0–1 | .... | 303 | 314 | 570 | 108 | 532 | 936 | Fair drainage |
| 11 | 14b | 1–2 | 3496 | 226 | 264 | 840 | 86 | 490 | 978 | " |
| 11 | 14c | 2–3 | 6700 | 459 | 517 | 1348 | 122 | 1503 | 1632 | " |
| 11 | 18 | 0–1 | 6480 | 527 | 172 | 516 | 524 | 1136 | 1140 | Good drainage |
| C | 16a | 0–1 | 127196 | 4460 | 137 | 30612 | 700 | 18376 | 55596 | Poor drainage |
| C | 16b | 1–2 | 73576 | 572 | 28 | 12660 | 956 | 5808 | 20524 | " |
| C | 16c | 2–3 | 34756 | 416 | 92 | 10344 | 780 | 5588 | 15940 | " |
| C | 17a | 0–1 | 11364 | 288 | ... | 2604 | 92 | 1088 | 2048 | Fair drainage |
| C | 17b | 1–2 | 9652 | 152 | 328 | 2360 | 220 | 1652 | 2616 | " |
| C | 17c | 2–3 | 11840 | 188 | 200 | 2644 | 704 | 2940 | 3650 | " |

TABLE II

CALCIUM, MAGNESIUM, SODIUM, POTASSIUM, HYDROGEN IN REPLACEABLE FORM AS PER CENT IN DRY SOILS AND AS PER CENT TOTAL REPLACEABLE BASES

| Field | Sample | Sample Depth | Drainage | Cane Growth | Reaction pH | Calcium Ca | Magnesium Mg | Sodium Na | Potassium K | Hydrogen H | Total Bases | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na | Ratio Potassium K | Milliequivalent (M. E.) Basis Calcium Ca | Milliequivalent (M. E.) Basis Magnesium Mg | Milliequivalent (M. E.) Basis Sodium Na | Milliequivalent (M. E.) Basis Potassium K | Milliequivalent (M. E.) Basis Hydrogen H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19B | 1 | 0–1 | Good | Good | 7.8 | .340 | .158 | .046 | .048 | .... | .592 | 57.5 | 26.7 | 7.8 | 8.1 | 16.9 | 13.0 | 2.0 | 1.2 | ... |
| 17A | 3 | 0–1 | " | " | 7.7 | .212 | .054 | .063 | .004 | .... | .333 | 63.7 | 16.2 | 19.0 | 1.2 | 10.6 | 4.4 | 2.7 | .1 | ... |
| 21A | 9 | 0–1 | " | " | 8.0 | .191 | .071 | .024 | .023 | .... | .309 | 62.0 | 23.0 | 7.8 | 7.4 | 9.5 | 5.8 | 1.0 | .6 | ... |
| 21A | 10 | 0–1 | " | " | 8.0 | .272 | .111 | .073 | .034 | .... | .490 | 55.5 | 22.7 | 14.9 | 7.0 | 13.6 | 8.9 | 3.2 | .8 | ... |
| 14 | 15a | 0–1 | Fair | " | 8.0 | .215 | .092 | .034 | .016 | .... | .357 | 60.2 | 25.8 | 9.5 | 4.5 | 10.7 | 7.5 | 1.5 | .4 | ... |
| 14 | 15b | 1–2 | " | " | 7.7 | .202 | .085 | .... | ... | .... | ... | .... | .... | .... | ... | 10.1 | 7.0 | ... | ... | ... |
| 14 | 15c | 2–3 | " | " | 7.5 | .184 | .082 | .032 | .004 | .... | .302 | 61.0 | 27.1 | 10.6 | 1.3 | 9.2 | 6.7 | 1.4 | .1 | ... |
| 26B | 2 | 0–1 | " | Fair | 8.0 | .557 | .368 | .066 | .084 | .... | 1.075 | 51.8 | 34.2 | 6.2 | 7.8 | 27.7 | 30.2 | 2.8 | 2.1 | ... |
| A | 19a | 0–1 | " | Good | 7.5 | .153 | .059 | .030 | .015 | .... | .257 | 59.6 | 22.9 | 11.7 | 5.8 | 7.6 | 4.8 | 1.3 | .4 | ... |
| A | 19b | 1–2 | " | " | 5.8 | .082 | .038 | .025 | .016 | .006 | .161 | 50.9 | 23.6 | 15.5 | 9.9 | 4.1 | 3.1 | 1.1 | .4 | 5.9 |
| A | 19c | 2–3 | " | " | 4.6 | .070 | .028 | .024 | .022 | .005 | .144 | 48.6 | 19.4 | 16.7 | 1.3 | 3.5 | 2.3 | 1.0 | .5 | 5.0 |
| A | 20a | 0–1 | " | " | 7.3 | .186 | .077 | .024 | .017 | .... | .304 | 61.2 | 25.3 | 7.9 | 5.6 | 9.3 | 6.3 | 1.0 | .4 | ... |
| A | 20b | 1–2 | " | " | 5.6 | .097 | .062 | .027 | .026 | .0058 | .212 | 45.8 | 29.2 | 12.7 | 12.3 | 4.8 | 5.1 | 1.2 | .6 | 5.7 |
| A | 20c | 2–3 | " | " | 5.3 | .094 | .067 | .030 | .009 | .002 | .200 | 47.0 | 33.4 | 15.0 | 4.6 | 4.7 | 5.5 | 1.3 | .2 | 2.0 |
| A | 20d | 3–4 | " | " | 5.1 | .140 | .142 | .051 | .009 | .005 | .342 | 40.9 | 41.5 | 14.9 | 2.6 | 7.0 | 11.6 | 2.2 | .2 | 5.0 |
| A | 21a | 0–1 | Good | " | 7.3 | .233 | .134 | .040 | .024 | .... | .431 | 54.6 | 31.1 | 9.3 | 5.5 | 11.6 | 11.0 | 1.7 | .6 | ... |
| A | 21b | 1–2 | " | " | 7.3 | .210 | .106 | .037 | .021 | .... | .374 | 56.2 | 28.3 | 9.9 | 5.6 | 10.5 | 8.7 | 1.6 | .5 | ... |
| A | 21c | 2–3 | " | " | 7.2 | .199 | .086 | .035 | .019 | .... | .339 | 58.7 | 25.4 | 10.3 | 5.6 | 9.9 | 7.1 | 1.5 | .5 | ... |
| 3D | 4a | 0–1 | Fair | " | 7.3 | .235 | .108 | .035 | .013 | .... | .391 | 60.0 | 27.6 | 8.8 | 3.3 | 11.7 | 8.9 | 1.5 | .3 | ... |
| 3D | 4b | 1–2 | " | " | 6.7 | .191 | .095 | .023 | .010 | .... | .319 | 60.0 | 30.0 | 7.2 | 3.0 | 9.5 | 7.8 | 1.0 | .2 | ... |
| 3D | 5 | 0–1 | Poor | Fair | 7.5 | .148 | .082 | .052 | .004 | .... | .286 | 51.9 | 28.7 | 18.2 | 1.4 | 7.4 | 6.7 | 2.2 | .1 | ... |
| 3D | 6 | 0–1 | " | " | 7.5 | .209 | .095 | .047 | .005 | .... | .356 | 58.7 | 26.7 | 13.3 | 1.4 | 10.4 | 7.8 | 2.0 | .1 | ... |
| 3D | 7 | 0–1 | " | " | 7.3 | .240 | .093 | .049 | .006 | .... | .388 | 62.0 | 24.0 | 12.6 | 1.6 | 11.9 | 7.6 | 2.1 | .1 | ... |
| 11 | 11a | 0–1 | " | Poor | 7.5 | .199 | .119 | .035 | .010 | .... | .354 | 56.2 | 33.6 | 10.0 | 2.8 | 9.9 | 9.8 | 1.5 | .2 | ... |
| 11 | 11b | 1–2 | " | " | 6.1 | .132 | .084 | .044 | .007 | .005 | .267 | 49.5 | 31.5 | 16.5 | 2.6 | 6.6 | 6.9 | 1.9 | .2 | 5.0 |
| 11 | 11c | 2–3 | " | " | 4.8 | .147 | .054 | .031 | .006 | .0085 | .238 | 61.8 | 22.7 | 13.0 | 2.5 | 7.3 | 4.4 | 1.3 | .1 | 8.4 |
| 11 | 12a | 0–1 | Fair | Fair | 7.7 | .209 | .116 | .042 | .042 | .... | .409 | 51.1 | 28.4 | 10.3 | 10.3 | 10.4 | 9.5 | 1.8 | 1.1 | ... |
| 11 | 12b | 1–2 | " | " | 7.7 | .201 | .108 | .035 | .009 | .... | .353 | 57.0 | 30.6 | 10.0 | 2.5 | 10.0 | 8.9 | 1.5 | .2 | ... |
| 11 | 12c | 2–3 | " | " | 7.5 | .195 | .109 | .047 | .007 | .... | .358 | 54.5 | 30.4 | 13.2 | 2.0 | 9.7 | 8.9 | 2.0 | .2 | ... |
| 11 | 13a | 0–1 | Poor | Poor | 7.7 | .198 | .116 | .077 | .015 | .... | .406 | 49.0 | 28.6 | 19.0 | 3.7 | 9.9 | 9.5 | 3.3 | .4 | ... |
| 11 | 13b | 1–2 | " | " | 6.5 | .221 | .056 | .069 | .096 | .006 | .362 | 63.0 | 15.9 | 19.6 | 1.7 | 11.0 | 4.6 | 3.0 | .1 | 5.9 |
| 11 | 13c | 2–3 | " | " | 5.3 | .176 | .065 | .049 | .009 | .0067 | .299 | 58.8 | 21.7 | 16.4 | 3.0 | 8.7 | 5.3 | 2.1 | .2 | 6.6 |
| 11 | 14a | 0–1 | Fair | Fair | 7.3 | .199 | .102 | .059 | .021 | .... | .381 | 52.3 | 26.8 | 15.5 | 5.5 | 9.9 | 8.4 | 2.5 | .5 | ... |
| 11 | 14b | 1–2 | " | " | 7.2 | .195 | .107 | .040 | .011 | .... | .355 | 55.2 | 30.3 | 11.3 | 3.1 | 9.7 | 8.8 | 1.7 | .3 | ... |
| 11 | 14c | 2–3 | " | " | 6.0 | .157 | .108 | .051 | .008 | .... | .324 | 48.5 | 33.4 | 15.8 | 2.4 | 7.8 | 8.9 | 2.2 | .2 | ... |
| 11 | 18 | 0–1 | Good | Good | 8.0 | .282 | .145 | .063 | .043 | .... | .533 | 53.0 | 27.2 | 11.8 | 8.1 | 14.1 | 11.9 | 2.7 | 1.1 | ... |
| C | 16a | 0–1 | Poor | Poor | 7.7 | .319 | .203 | .290 | .083 | .... | .895 | 35.6 | 22.6 | 32.6 | 9.2 | 15.9 | 16.6 | 12.5 | 2.1 | ... |
| C | 16b | 1–2 | " | " | 7.8 | .267 | .150 | .237 | .014 | .... | .668 | 40.0 | 22.4 | 35.4 | 2.1 | 13.3 | 12.3 | 10.3 | .3 | ... |
| C | 16c | 2–3 | " | " | 7.0 | .247 | .140 | .288 | .011 | .... | .686 | 36.0 | 20.4 | 42.0 | 1.6 | 12.3 | 11.5 | 12.5 | .3 | ... |
| C | 17 | 0–1 | Fair | Fair | 8.2 | .326 | .078 | .103 | .036 | .... | .543 | 60.0 | 14.3 | 19.0 | 6.7 | 16.3 | 6.4 | 4.4 | .9 | ... |
| C | 17 | 1–2 | " | " | 7.5 | .266 | .108 | .131 | .022 | .... | .527 | 50.4 | 20.5 | 24.8 | 4.2 | 13.3 | 8.9 | 5.6 | .6 | ... |
| C | 17 | 2–3 | " | " | 7.0 | .162 | .123 | .211 | .004 | .... | .500 | 32.4 | 24.6 | 42.2 | 0.8 | 8.1 | 10.1 | 9.1 | .1 | ... |

An installation of tile drains had just been made in Field 3D a few months prior to the sampling. The crop was about six months old at this time. Samples of soil and subsoil were taken near one of the drain wells where cane was growing well and drainage had noticeably improved, as compared with the rest of the field. Three other samples were taken in areas which had not yet shown an improvement in drainage. The soils from the three latter areas were in poor mechanical condition and drainage was poor, all of which was reflected in a retarded cane growth. It may be seen that the principal abnormality in these samples is in the notably higher zeolite sodium in the poorly drained soils. This fact is undoubtedly associated with the soil properties above mentioned. On the other hand, the zeolite sodium has been materially reduced where the drainage has been improved, with a corresponding improvement in cane growth and soil texture. This field should be quite rapidly reclaimed on account of the high content of zeolite calcium.

Previous to 1920, Field 11 had given some trouble on account of a high water table. Tile drains were therefore installed for the purpose of lowering this table in order that the cane could be more effectively ripened. This was one of the original tile drain installations in the Islands and it was due to the success here that additional installations were made in Fields 3D and C. At the time the soil samples were taken (1927), the third ratoon crop was just starting and there were several areas in the field where the stand was very poor, and still others where there was no stand at all and replanting was necessary. The soil texture was notably heavier in the poor areas, and in some cases considerable salt efflorescence was visible. In the good areas, especially in the line directly over the tile, there was an excellent stand of cane and drainage was well regulated by a better mechanical condition of the soil. Two poor areas and two good areas were sampled. Sample 11 was taken from an area where the stand was poor and sample 13 where

Fig. 1. This figure shows the effect of salt accumulation on soil and cane growth in Field C.

there was practically no stand at all. The first, second and third foot were sampled separately. There is remarkably little difference in the zeolite base content of these samples, but a notable difference in soil reaction and zeolite hydrogen. On the basis of ratio of sodium to the total bases present, it is slightly higher in the poor areas which, along with the higher acidity, is probably related to the dispersion of the clay.

There has been from time to time considerable salt accumulation in Field C, but only in a small area, a low spot, has the accumulation become serious. In fact, in this area saline toxicity has exceeded the limit of tolerance of H 109 as shown in Fig. 1. Tile drains have been installed in this field as a step toward reclamation. As in Fields 3D and 11, where drainage had been improved, notably over the line of tile and near the drain wells, cane had already started to make a stand in this field. Soil samples were taken to a three-foot depth in one area where cane could not grow, and in a second area near the drain well where the soil had "opened up". There is a higher percentage of zeolite magnesium and sodium and also higher replacement capacity in the poorly drained toxic area, which is true also when the results are expressed on a milliequivalent basis. This is undoubtedly the cause of the low permeability in this field.

## Comparison With Mainland Alkali Soil

A comparison of the data presented in Table I with the classification which Kelley has made of mainland soils is quite illuminating. It appears to be a significant characteristic of Ewa soils, which have been irrigated with artesian water, to be consistently higher in zeolite magnesium than mainland soils, and this introduces somewhat of a complication in using his classification. On the whole, though, the following deductions are reasonable. In Field A the samples taken from poor areas can be classed as intermediate saline types, while the third sample, except for its higher zeolite magnesium, can be classed as a good type. In Field 3D the sample from the good area can be classified as a good type, while the three samples from poor areas having a high zeolite sodium are placed in the intermediate class. In Field 11 all the samples are in the intermediate class, principally on account of a low calcium and high magnesium. The soil in Field C makes the nearest approach to a bad saline type, but still falls short of the minimum 50 per cent ratio for zeolite sodium in the bad soils examined by Kelley.

## Salt Accumulation

Poorly drained irrigated soils are usually characterized by high saline accumulation, hence we find in Table I a wide variation in the salt content of the soil solution in this set of fields. In Field A the accumulation of sodium in the third and fourth foot is significant and probably a result of the puddled condition of this subsoil. The greater salt accumulation in the two poor areas, as compared with the good, is also a significant factor. The same is true in Field 3D where the higher salt content of the soil solution is associated with the poorly drained areas

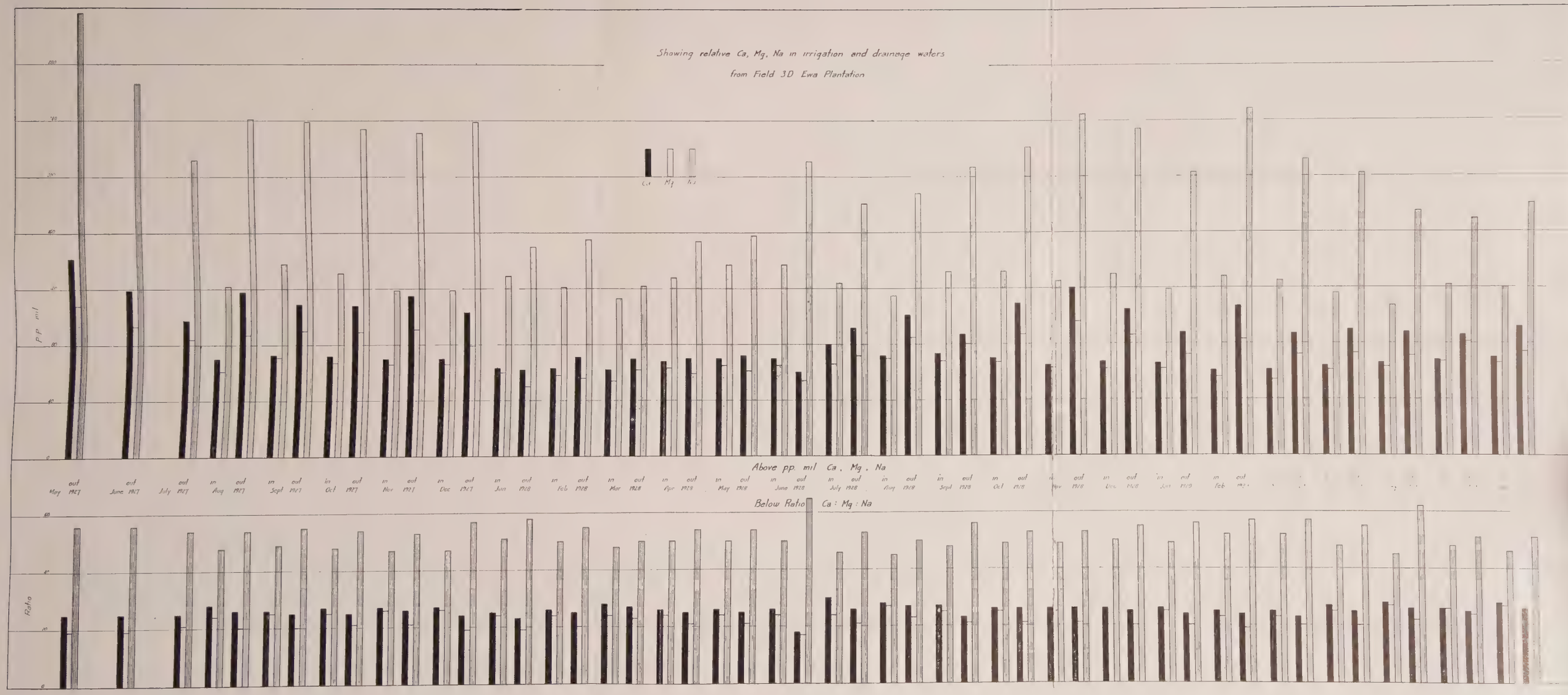


Fig. 2. Showing relative Ca, Mg and Na in irrigation and drainage waters from Field 3D.

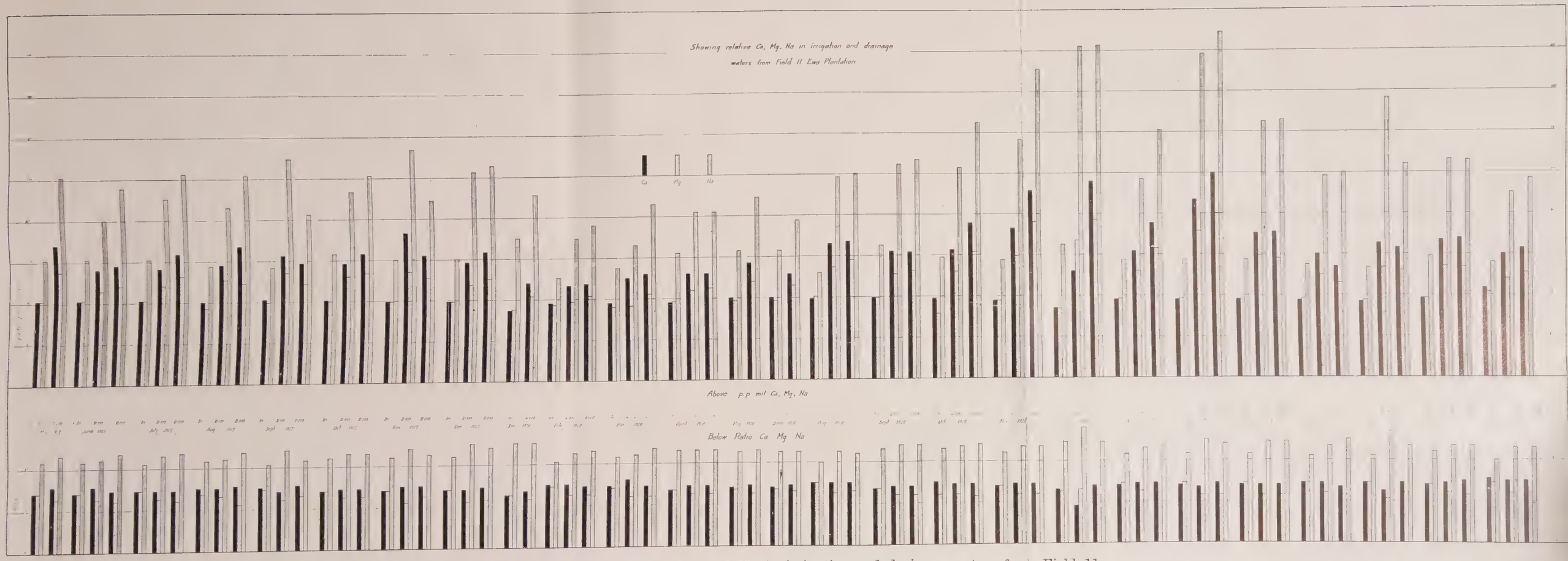
Showing relative Ca, Mg, Na in irrigation and drainage
waters from Field II Ewa Plantation
Ca
Mg
Na
Above p.p mil Ca, Mg, Na
Below Ratio Ca Mg Na

Fig. 3. Showing relative Ca, Mg and Na in irrigation and drainage waters from Field 11.

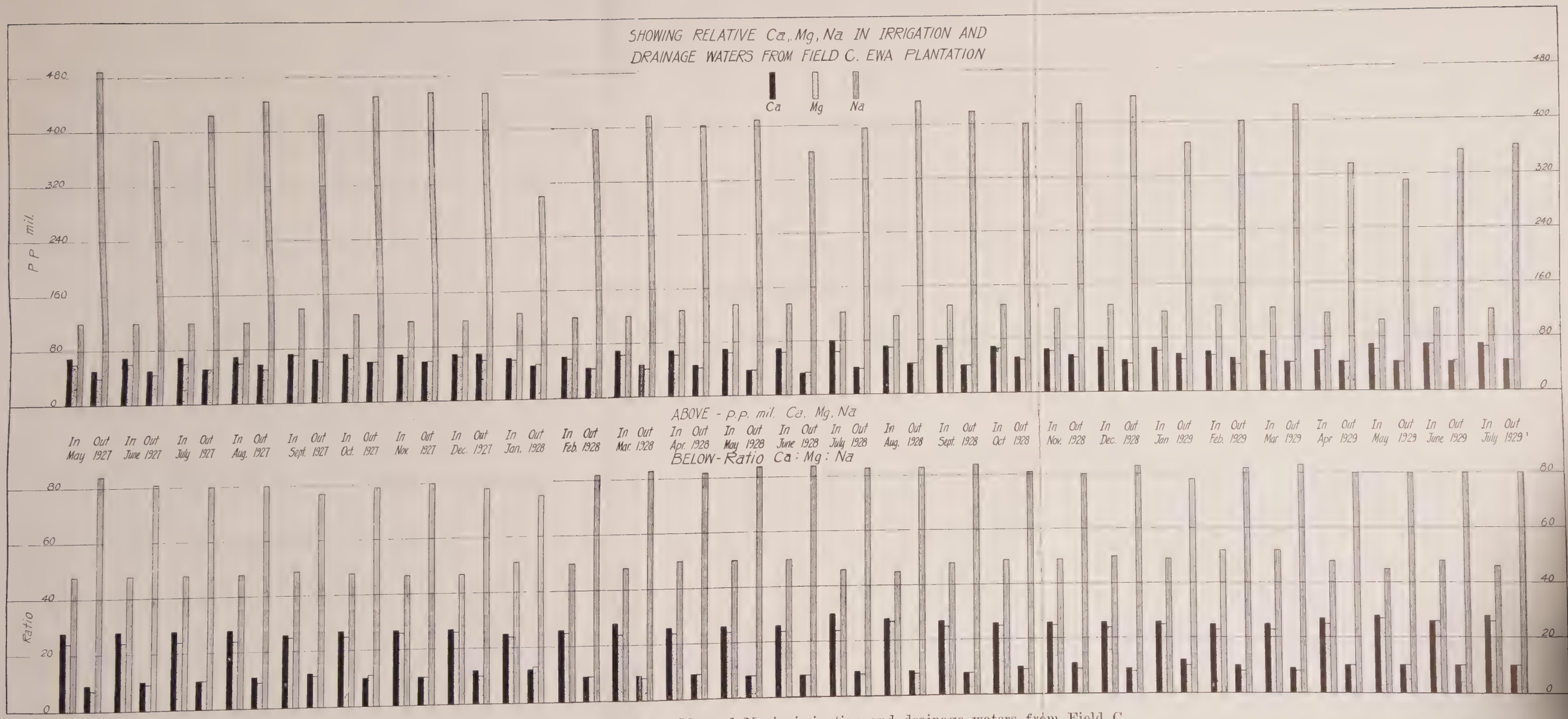


Fig. 4. Showing relative Ca, Mg and Na in irrigation and drainage waters from Field C.

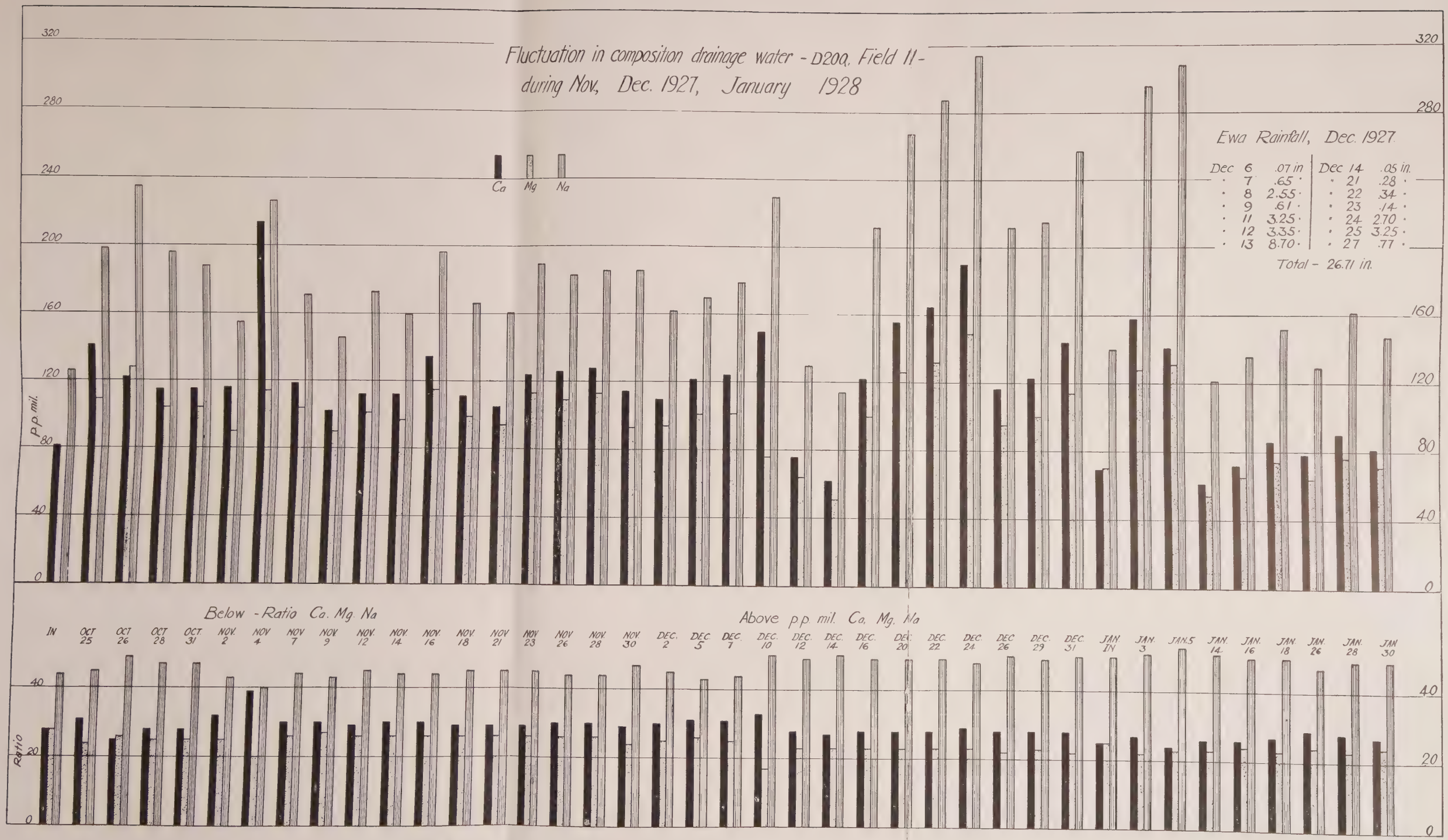


Fig. 5. Showing variation in waters during November and December, 1928, and January, 1929.

and retarded cane growth. Again, in Field 11 the same relation between salt accumulation, low permeability and cane growth run hand in hand. In the small section of Field C the soil solution has reached a concentration three times that of the Pacific Ocean water, and the soil is practically barren of vegetation. This has shown a remarkable reduction from 127,196 to 11,364 parts per million in the area where the soil is more permeable as a result of the tile drains and indicates the efficiency with which our Island saline soils can be reclaimed by tile drainage.

## Tile Drainage

It is evident from the preceding data and discussion that none of the Ewa soils are in a chemical or physical state closely approaching a bad saline type. They are still quite high in replaceable calcium, while many of the bad alkali types on the mainland contain no calcium whatever as zeolite. On the other hand, a number of the Ewa soils are of intermediate types and abnormally high in zeolite magnesium. But since this is known to be a character of many Island soils which have never been irrigated with artesian water, we have no evidence in the preceding data that its presence in Ewa soils is due to the use of saline water. In order to study this question, as well as any other progressive changes taking place in the soil, the tile drained fields offered a possibility in the relation between the composition of the irrigation water being applied to the fields and as it was discharged from the drains, as compared with the composition and properties of the soil. So, at our request, the department of research and control at Ewa Plantation Company has been supplying us with composite water samples representing the monthly irrigation and drainage from Fields 11, 3D and C. Complete analyses of all these waters have been made, and the results are given in Tables III, IV, V, and shown graphically in Figs. 2, 3, 4 and 5. Only calcium, magnesium and sodium, the three bases which have the greatest influence upon the soil properties, are given graphically in terms of the ratio of each to the total of all three, and as parts per million. It is the ratio of one base to the others, rather than concentration, which governs fixation and exchange. In some cases, as noted in the tables, single water samples were analyzed, in addition to composites, in order to determine daily fluctuations, and for other reasons which will be mentioned later.

TABLE III

Showing Composition of Irrigation Water (In) and Drainage Water (Out)

Field 3D, Ewa Plantation Company, May, 1927, to July, 1929

| Date of Sample | Water | Chlorine | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| May, 1927 | Out | 844 | 2358 | 141 | 108 | 246 | 316 | 13 | 25 | 19 | 56 |
| June, 1927 | Out | 732 | 2164 | 119 | 93 | 199 | 266 | 9 | 25 | 19 | 56 |
| July, 1927 | Out | 580 | 1604 | 97 | 84 | 144 | 212 | 4 | 25 | 21 | 54 |
| Aug., 1927 | In | 422 | 1211 | 70 | 61 | 78 | 122 | 12 | 28 | 24 | 48 |
| " | Out | 702 | 1777 | 118 | 87 | 173 | 241 | 5 | 26 | 20 | 54 |
| Sept., 1927 | In | 422 | 1230 | 73 | 71 | 79 | 138 | 6 | 26 | 25 | 49 |
| " | Out | 688 | 1730 | 109 | 89 | 165 | 239 | 3 | 25 | 20 | 55 |
| Oct., 1927 | In | 428 | 1124 | 72 | 67 | 81 | 131 | 4 | 27 | 25 | 48 |
| " | Out | 666 | 1635 | 108 | 89 | 141 | 234 | 4 | 25 | 21 | 54 |
| Nov., 1927 | In | 420 | 1155 | 70 | 66 | 75 | 119 | 5 | 27 | 26 | 47 |
| " | Out | 715 | 1721 | 115 | 91 | 148 | 231 | 5 | 26 | 21 | 53 |
| Dec., 1927 | In | 420 | 1155 | 70 | 66 | 75 | 119 | 5 | 27 | 26 | 47 |
| " | Out | 612 | 1635 | 103 | 79 | 170 | 239 | 7 | 24 | 19 | 57 |
| Jan., 1928 | In | 372 | 921 | 63 | 60 | 68 | 129 | 9 | 25 | 24 | 51 |
| " | Out | 364 | 1889 | 62 | 50 | 95 | 150 | 6 | 23 | 19 | 58 |
| Feb., 1928 | In | 378 | 1000 | 63 | 58 | 73 | 121 | 9 | 26 | 24 | 50 |
| " | Out | 406 | 1081 | 71 | 56 | 108 | 155 | 8 | 25 | 20 | 55 |
| Mar., 1928 | In | 359 | 1102 | 62 | 54 | 79 | 113 | .. | 27 | 23 | 50 |
| " | Out | 394 | 1154 | 70 | 62 | 76 | 122 | .. | 28 | 24 | 48 |

| Date of Sample | Water | Chlorine | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium | Ratio Magnesium | Ratio Sodium |
|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1928 | In | 411 | 1076 | 68 | 63 | 81 | 128 | 5 | 26 | 24 | 50 |
| " | Out | 397 | 1079 | 70 | 59 | 92 | 154 | 4 | 25 | 21 | 54 |
| May, 1928 | In | 393 | 1113 | 70 | 65 | 75 | 137 | 4 | 26 | 24 | 50 |
| " | Out | 400 | 1137 | 72 | 61 | 86 | 158 | 2 | 25 | 21 | 54 |
| June, 1928 | In | 393 | 1113 | 70 | 65 | 75 | 137 | 4 | 26 | 24 | 50 |
| " | Out | 360 | 1003 | 60 | 54 | 76 | 211 | .. | 18 | 17 | 65 |
| July, 1928 | In | 418 | 1182 | 80 | 66 | 73 | 124 | 12 | 30 | 24 | 46 |
| " | Out | 545 | 1449 | 92 | 74 | 108 | 181 | 8 | 26 | 21 | 53 |
| Aug., 1928 | In | 432 | 1201 | 72 | 70 | 77 | 115 | 6 | 28 | 27 | 45 |
| " | Out | 631 | 1714 | 101 | 85 | 125 | 188 | 7 | 27 | 23 | 50 |
| Sept., 1928 | In | 425 | 1118 | 73 | 68 | 81 | 132 | 9 | 27 | 25 | 48 |
| " | Out | 581 | 1490 | 87 | 80 | 117 | 207 | 8 | 23 | 21 | 56 |
| Oct., 1928 | In | 422 | 1199 | 70 | 67 | 81 | 132 | 7 | 26 | 25 | 49 |
| " | Out | 588 | 1644 | 109 | 87 | 122 | 221 | 6 | 26 | 21 | 53 |
| Nov., 1928 | In | 400 | 996 | 65 | 63 | 74 | 125 | 9 | 26 | 25 | 49 |
| " | Out | 695 | 1706 | 120 | 96 | 133 | 246 | 6 | 26 | 21 | 53 |
| Dec., 1928 | In | 380 | 902 | 67 | 62 | 74 | 130 | 9 | 26 | 24 | 50 |
| " | Out | 620 | 1539 | 105 | 86 | 127 | 234 | 6 | 25 | 20 | 55 |
| Jan., 1929 | In | 386 | 1041 | 66 | 62 | 75 | 119 | 6 | 26 | 25 | 49 |
| " | Out | 553 | 1371 | 88 | 72 | 110 | 203 | 6 | 24 | 20 | 56 |
| Feb., 1929 | In | 361 | 966 | 61 | 56 | 73 | 128 | 6 | 25 | 23 | 52 |
| " | Out | 623 | 1440 | 107 | 83 | 131 | 247 | 6 | 24 | 19 | 57 |

| Date of Sample | Water | Chlorine | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar., 1929 | In | 347 | 920 | 61 | 54 | 68 | 125 | 10 | 25 | 23 | 52 |
| " | Out | 482 | 1301 | 87 | 72 | 102 | 212 | 13 | 23 | 20 | 57 |
| April, 1929 | In | 387 | 1072 | 64 | 61 | 64 | 116 | .. | 27 | 25 | 48 |
| " | Out | 524 | 1436 | 90 | 73 | 104 | 202 | .. | 25 | 20 | 55 |
| May, 1929 | In | 402 | 1059 | 66 | 63 | 73 | 107 | .. | 28 | 27 | 45 |
| " | Out | 525 | 1367 | 88 | 71 | 98 | 175 | .. | 26 | 22 | 52 |
| June, 1929 | In | 403 | 1086 | 68 | 67 | 75 | 122 | .. | 26 | 26 | 48 |
| " | Out | 515 | 1319 | 86 | 81 | 95 | 169 | .. | 25 | 24 | 51 |

TABLE IV

Showing Composition of Irrigation Water (In) and Drainage Water (Out)

Field 11, Ewa Plantation Company, May, 1927, to July, 1929

| Date of Sample | Water | Chlorine Cl | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| May, 1927 | Out D100 | 720 | 2184 | 136 | 110 | 201 | 202 | 10 | 31 | 25 | 46 |
| June, 1927 | In | 440 | 1524 | 79 | 77 | 84 | ... | 6 | .. | .. | .. |
| " | Out D100 | 582 | 1846 | 112 | 91 | 144 | 160 | 14 | 31 | 25 | 44 |
| " | Out D200 | 632 | 2062 | 116 | 96 | 163 | 191 | 11 | 29 | 24 | 47 |
| July, 1927 | In | 454 | 1420 | 82 | 82 | 87 | 122 | 5 | 29 | 29 | 42 |
| " | Out D100 | 596 | 1814 | 113 | 96 | 145 | 181 | 7 | 29 | 25 | 46 |
| " | Out D200 | 658 | 1990 | 127 | 105 | 155 | 204 | 4 | 29 | 24 | 47 |
| Aug., 1927 | In | 450 | 1255 | 80 | 74 | 82 | 115 | 10 | 30 | 27 | 43 |
| " | Out D100 | 626 | 1707 | 116 | 101 | 140 | 172 | 10 | 30 | 26 | 44 |
| " | Out D200 | 696 | 1801 | 134 | 98 | 107 | 203 | 7 | 31 | 22 | 47 |

| Date of Sample | Water | Chlorine Cl | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept., 1927 | In | 448 | 1258 | 82 | 79 | 97 | 113 | 6 | 30 | 29 | 41 |
| " | Out D100 | 730 | 1867 | 125 | 108 | 163 | 219 | 8 | 28 | 24 | 48 |
| " | Out D200 | 624 | 1688 | 117 | 97 | 133 | 165 | 9 | 31 | 26 | 43 |
| Oct., 1927 | In | 458 | 1337 | 81 | 80 | 89 | 126 | 7 | 28 | 28 | 44 |
| " | Out D100 | 670 | 1748 | 117 | 104 | 140 | 187 | 6 | 29 | 25 | 46 |
| " | Out D200 | 708 | 1854 | 126 | 107 | 144 | 202 | 8 | 29 | 25 | 46 |
| Oct. 25, 1927 | " | 704 | 1785 | 141 | 109 | 142 | 198 | 5 | 31 | 24 | 45 |
| Oct. 26, 1927 | " | 856 | 2145 | 122 | 128 | 181 | 235 | 6 | 25 | 26 | 49 |
| Oct. 28, 1927 | " | 690 | 1770 | 115 | 104 | 135 | 196 | 6 | 28 | 25 | 47 |
| Oct. 31, 1927 | " | 652 | 1649 | 115 | 104 | 125 | 188 | 4 | 28 | 25 | 47 |
| Nov., 1927 | In | 470 | 1130 | 79 | 79 | 83 | 120 | 5 | 28 | 28 | 44 |
| " | Out D100 | 845 | 1912 | 146 | 108 | 185 | 227 | 13 | 30 | 22 | 48 |
| " | Out D200 | 709 | 1746 | 124 | 102 | 135 | 177 | 9 | 30 | 25 | 45 |
| Nov. 2, 1927 | Out D200 | 600 | 1486 | 116 | 90 | 111 | 155 | 12 | 32 | 25 | 43 |
| Nov. 4, 1927 | " | 1240 | 2772 | 214 | 114 | 232 | 227 | 13 | 39 | 21 | 40 |
| Nov. 7, 1927 | " | 680 | 1619 | 119 | 104 | 128 | 171 | 10 | 30 | 26 | 44 |
| Nov. 9, 1927 | " | 580 | 1365 | 102 | 90 | 111 | 146 | 11 | 30 | 27 | 43 |
| Nov. 12, 1927 | " | 675 | 1593 | 112 | 101 | 127 | 173 | 10 | 29 | 26 | 45 |
| Nov. 14, 1927 | " | 630 | 1616 | 112 | 97 | 112 | 160 | 10 | 30 | 26 | 44 |
| Nov. 16, 1927 | " | 675 | 1897 | 135 | 115 | 147 | 197 | 13 | 30 | 26 | 44 |
| Nov. 18, 1927 | " | 645 | 1574 | 111 | 99 | 125 | 166 | 9 | 29 | 26 | 45 |
| Nov. 21, 1927 | " | 615 | 1575 | 105 | 94 | 124 | 161 | 11 | 29 | 26 | 45 |
| Nov. 23, 1927 | " | 735 | 1790 | 124 | 113 | 140 | 190 | 2 | 29 | 26 | 45 |
| Nov. 26, 1927 | " | 725 | 1805 | 126 | 109 | 137 | 183 | 2 | 30 | 26 | 44 |
| Nov. 28, 1927 | " | 740 | 1873 | 128 | 113 | 137 | 186 | 6 | 30 | 26 | 44 |
| Nov. 30, 1927 | " | 675 | 1730 | 114 | 93 | 130 | 186 | 6 | 29 | 24 | 47 |
| Dec., 1927 | In | 470 | 1130 | 79 | 79 | 83 | 120 | 5 | 28 | 28 | 44 |
| " | Out D100 | 624 | 1721 | 117 | 95 | 205 | 205 | 8 | 28 | 22 | 50 |
| " | Out D200 | 693 | 1814 | 127 | 100 | 168 | 211 | 6 | 29 | 23 | 48 |

| Date of Sample | Water | Chlorine Cl | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec. 2, 1927 | Out D200 | 602 | 1555 | 110 | 94 | 121 | 161 | 11 | 30 | 25 | 45 |
| Dec. 5, 1927 | " | 658 | 1675 | 122 | 101 | 126 | 170 | 14 | 31 | 26 | 43 |
| Dec. 7, 1927 | " | 666 | 1713 | 124 | 101 | 140 | 179 | 4 | 31 | 25 | 44 |
| Dec. 10, 1927 | " | 824 | 2094 | 150 | 76 | 173 | 230 | 4 | 33 | 17 | 50 |
| Dec. 12, 1927 | " | 400 | 1079 | 76 | 64 | 120 | 130 | 4 | 28 | 23 | 49 |
| Dec. 14, 1927 | " | 316 | 890 | 62 | 51 | 126 | 114 | 5 | 27 | 23 | 50 |
| Dec. 16, 1927 | " | 652 | 1752 | 122 | 100 | 180 | 212 | 2 | 28 | 23 | 49 |
| Dec. 20, 1927 | " | 864 | 2184 | 155 | 126 | 207 | 267 | 4 | 28 | 23 | 49 |
| Dec. 22, 1927 | " | 920 | 2367 | 165 | 132 | 217 | 288 | 4 | 28 | 23 | 49 |
| Dec. 24, 1927 | " | 1048 | 2620 | 190 | 149 | 235 | 314 | 6 | 29 | 23 | 48 |
| Dec. 26, 1927 | " | 630 | 1692 | 117 | 95 | 110 | 212 | 4 | 28 | 22 | 50 |
| Dec. 29, 1927 | " | 672 | 1871 | 122 | 100 | 207 | 215 | 7 | 28 | 23 | 49 |
| Dec. 31, 1927 | " | 768 | 2094 | 144 | 114 | 226 | 257 | 5 | 28 | 22 | 50 |
| Jan., 1928 | In | 392 | 988 | 69 | 70 | 72 | 140 | 9 | 25 | 25 | 50 |
| " | Out D200 | 533 | 1346 | 96 | 83 | 133 | 181 | 6 | 27 | 23 | 50 |
| Jan. 3, 1928 | " | 892 | 2149 | 158 | 128 | 239 | 296 | 5 | 27 | 22 | 51 |
| Jan. 5, 1928 | " | 924 | 2152 | 141 | 131 | 243 | 308 | 8 | 24 | 23 | 53 |
| Jan. 14, 1928 | " | 308 | 892 | 61 | 54 | 78 | 121 | 6 | 26 | 23 | 51 |
| Jan. 16, 1928 | " | 392 | 1068 | 72 | 65 | 90 | 136 | 5 | 26 | 24 | 50 |
| Jan. 18, 1928 | " | 432 | 1290 | 86 | 74 | 106 | 152 | 5 | 27 | 23 | 50 |
| Jan. 26, 1928 | " | 392 | 965 | 78 | 64 | 79 | 127 | 8 | 29 | 24 | 47 |
| Jan. 28, 1928 | " | 476 | 1162 | 90 | 76 | 121 | 161 | 6 | 28 | 23 | 49 |
| Jan. 30, 1928 | " | 448 | 1088 | 82 | 71 | 111 | 147 | 5 | 27 | 24 | 49 |
| Feb., 1928 | In | 426 | 1098 | 76 | 74 | 81 | 101 | 12 | 30 | 29 | 41 |
| " | Out D100 | 483 | 1229 | 93 | 77 | 129 | 139 | 12 | 30 | 25 | 45 |
| " | Out D200 | 532 | 1348 | 95 | 83 | 115 | 152 | 9 | 29 | 25 | 46 |
| Mar., 1928 | In | 426 | 1202 | 76 | 72 | 79 | 110 | .. | 29 | 28 | 43 |
| " | Out D100 | 478 | 1366 | 100 | 75 | 100 | 132 | .. | 32 | 24 | 43 |
| " | Out D200 | 576 | 1556 | 104 | 85 | 116 | 172 | .. | 29 | 24 | 47 |

| Date of Sample | Water | Chlorine Cl | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1928 | In | 439 | 1187 | 76 | 77 | 80 | 124 | 7 | 27 | 27 | 46 |
| " | Out D100 | 552 | 1450 | 104 | 88 | 112 | 164 | 5 | 29 | 25 | 46 |
| " | Out D200 | 552 | 1462 | 104 | 90 | 112 | 164 | 4 | 29 | 25 | 46 |
| May, 1928 | In | 425 | 1211 | 80 | 77 | 80 | 126 | 3 | 28 | 27 | 45 |
| " | Out D200 | 588 | 1614 | 114 | 96 | 115 | 178 | 4 | 29 | 25 | 46 |
| June, 1928 | In | 425 | 1211 | 80 | 77 | 80 | 126 | 3 | 28 | 27 | 45 |
| " | Out D200 | 552 | 1488 | 103 | 92 | 99 | 155 | 7 | 29 | 26 | 45 |
| Aug., 1928 | In | 450 | 1244 | 79 | 81 | 80 | 104 | 5 | 30 | 30 | 40 |
| " | Out D100 | 705 | 1868 | 132 | 109 | 194 | 197 | 6 | 30 | 25 | 45 |
| " | Out D200 | 769 | 1987 | 134 | 116 | 181 | 200 | 7 | 30 | 26 | 44 |
| Sept., 1928 | In | 446 | 1219 | 79 | 79 | 84 | 130 | 7 | 27 | 27 | 46 |
| " | Out D100 | 687 | 1746 | 124 | 102 | 164 | 209 | 9 | 28 | 24 | 48 |
| " | Out D200 | 673 | 1752 | 123 | 105 | 165 | 214 | 7 | 28 | 24 | 48 |
| Oct., 1928 | In | 453 | 1250 | 78 | 63 | 84 | 118 | 12 | 30 | 24 | 46 |
| " | Out D100 | 666 | 1798 | 125 | 104 | 161 | 206 | 8 | 29 | 24 | 47 |
| " | Out D200 | 790 | 2164 | 151 | 123 | 205 | 250 | 5 | 29 | 23 | 48 |
| Nov., 1928 | In | 435 | 1128 | 75 | 75 | 79 | 115 | 10 | 28 | 28 | 44 |
| " | Out D100 | 738 | 1927 | 146 | 119 | 200 | 233 | 8 | 29 | 24 | 47 |
| " | Out D200 | 960 | 2522 | 183 | 152 | 249 | 302 | 9 | 29 | 24 | 47 |
| Dec., 1928 | In | 390 | 1016 | 68 | 67 | 76 | 130 | 6 | 26 | 25 | 49 |
| " | Out D100 | 970 | 2370 | 104 | 154 | 276 | 324 | 5 | 18 | 26 | 56 |
| " | Out D200 | 1010 | 2505 | 192 | 154 | 256 | 325 | 8 | 28 | 23 | 49 |
| Jan., 1929 | In | 425 | 1185 | 76 | 77 | 81 | 115 | 11 | 28 | 29 | 43 |
| " | Out D100 | 634 | 1686 | 123 | 104 | 168 | 194 | 7 | 29 | 25 | 46 |
| " | Out D200 | 797 | 2085 | 151 | 126 | 192 | 242 | 6 | 29 | 24 | 47 |

| Date of Sample | Water | Chlorine Cl | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Feb., 1929 | In | 425 | 1185 | 76 | 77 | 81 | 115 | 11 | 28 | 29 | 43 |
| " | Out D100 | 964 | 2310 | 174 | 143 | 269 | 317 | 4 | 27 | 23 | 50 |
| " | Out D200 | 1063 | 2565 | 200 | 160 | 270 | 338 | 5 | 29 | 23 | 48 |
| Mar., 1929 | In | 425 | 1185 | 76 | 77 | 81 | 115 | 11 | 28 | 29 | 43 |
| " | Out D100 | 723 | 1978 | 141 | 119 | 194 | 250 | 8 | 28 | 23 | 49 |
| " | Out D200 | 716 | 1969 | 142 | 116 | 180 | 252 | 8 | 28 | 23 | 49 |
| April, 1929 | In | 423 | 1200 | 75 | 77 | 76 | 110 | .. | 29 | 29 | 42 |
| " | Out D100 | 635 | 1707 | 120 | 100 | 139 | 197 | .. | 29 | 24 | 47 |
| " | Out D200 | 591 | 1590 | 108 | 92 | 126 | 200 | .. | 27 | 23 | 50 |
| May, 1929 | In | 424 | 1171 | 76 | 77 | 74 | 107 | .. | 29 | 29 | 42 |
| " | Out D100 | 719 | 1823 | 131 | 107 | 165 | 273 | .. | 25 | 21 | 54 |
| " | Out D200 | 683 | 1808 | 127 | 104 | 141 | 209 | .. | 29 | 24 | 47 |
| June, 1929 | In | 432 | 1196 | 77 | 77 | 72 | 118 | .. | 28 | 28 | 44 |
| " | Out D100 | 714 | 1846 | 133 | 108 | 168 | 213 | .. | 29 | 24 | 47 |
| " | Out D200 | 727 | 1860 | 136 | 107 | 154 | 212 | .. | 30 | 23 | 47 |

TABLE V

Showing Composition of Irrigation Water (In) and Drainage Water (Out)

Field C, Ewa Plantation Company, May, 1927, to July, 1929

| Date of Sample | Water | Chlorine Cl | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| May, 1927 | Out | 790 | 1840 | 50 | 38 | 205 | 488 | 9 | 9 | 7 | 84 |
| June, 1927 | Out | 672 | 1614 | 50 | 44 | 143 | 387 | 9 | 10 | 9 | 81 |
| July, 1927 | Out | 714 | 1676 | 54 | 53 | 138 | 425 | 3 | 10 | 10 | 80 |
| Aug., 1927 | In | 422 | 1211 | 70 | 61 | 78 | 122 | 13 | 28 | 24 | 48 |
| " | Out | 778 | 1856 | 58 | 52 | 151 | 445 | 4 | 11 | 9 | 80 |
| Sept., 1927 | In | 442 | 1230 | 73 | 71 | 79 | 138 | 6 | 26 | 25 | 49 |
| " | Out | 786 | 1835 | 65 | 62 | 171 | 424 | 6 | 12 | 11 | 77 |
| Oct., 1927 | In | 428 | 1124 | 72 | 67 | 81 | 131 | 4 | 27 | 25 | 48 |
| " | Out | 792 | 1825 | 59 | 60 | 168 | 451 | 5 | 10 | 11 | 79 |
| Nov., 1927 | In | 420 | 1155 | 70 | 66 | 75 | 119 | 5 | 27 | 26 | 47 |
| " | Out | 810 | 1804 | 59 | 60 | 169 | 456 | 6 | 10 | 10 | 80 |
| Dec., 1927 | In | 420 | 1155 | 70 | 66 | 75 | 119 | 5 | 27 | 26 | 47 |
| " | Out | 772 | 1823 | 68 | 60 | 176 | 455 | 12 | 12 | 10 | 78 |
| Jan., 1928 | In | 372 | 921 | 63 | 60 | 67 | 129 | 9 | 25 | 24 | 51 |
| " | Out | 728 | 1648 | 50 | 53 | 162 | 302 | 6 | 12 | 13 | 75 |
| Feb., 1928 | In | 378 | 1000 | 63 | 58 | 73 | 121 | 9 | 26 | 24 | 50 |
| " | Out | 658 | 1523 | 45 | 44 | 153 | 396 | 6 | 9 | 9 | 82 |
| Mar., 1928 | In | 394 | 1154 | 70 | 62 | 76 | 122 | 16 | 28 | 24 | 48 |
| " | Out | 655 | 1500 | 48 | 42 | 143 | 417 | 15 | 9 | 8 | 83 |

| Date of Sample | Water | Chlorine Cl | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1928 | In | 411 | 1076 | 68 | 63 | 81 | 128 | 5 | 26 | 24 | 50 |
| " | Out | 652 | 1456 | 46 | 43 | 142 | 404 | 2 | 9 | 9 | 82 |
| May, 1928 | In | 393 | 1113 | 70 | 65 | 75 | 137 | 4 | 26 | 24 | 50 |
| " | Out | 602 | 1383 | 38 | 39 | 132 | 411 | 7 | 8 | 8 | 84 |
| June, 1928 | In | 393 | 1113 | 70 | 65 | 75 | 137 | 4 | 26 | 24 | 50 |
| " | Out | 580 | 1325 | 34 | 35 | 123 | 364 | 9 | 8 | 8 | 84 |
| July, 1928 | In | 418 | 1182 | 80 | 66 | 73 | 124 | 12 | 30 | 24 | 46 |
| " | Out | 638 | 1440 | 44 | 38 | 135 | 393 | 8 | 9 | 8 | 83 |
| July 23, 1928 | Out | 577 | 1283 | 34 | 33 | 116 | 356 | 14 | 8 | 7 | 85 |
| July 26, 1928, | Out | 570 | 1267 | 32 | 33 | 113 | 363 | 12 | 7 | 8 | 85 |
| July 30, 1928 | Out | 588 | 1347 | 40 | 38 | 121 | 364 | 6 | 9 | 9 | 82 |
| July 31, 1928 | Out | 567 | 1272 | 34 | 33 | 113 | 359 | 12 | 8 | 8 | 84 |
| Aug., 1928 | In | 432 | 1201 | 72 | 70 | 77 | 115 | 6 | 28 | 27 | 45 |
| " | Out | 700 | 1592 | 46 | 44 | 149 | 436 | 8 | 9 | 8 | 83 |
| Aug. 1, 1928 | Out | 744 | 1635 | 47 | 45 | 159 | 431 | 5 | 9 | 9 | 82 |
| Aug. 4, 1928 | Out | 786 | 1801 | 57 | 53 | 166 | 454 | 4 | 10 | 9 | 81 |
| Aug. 6, 1928 | Out | 744 | 1676 | 46 | 43 | 156 | 434 | 8 | 9 | 8 | 83 |
| Aug. 8, 1928 | Out | 645 | 1418 | 37 | 38 | 130 | 395 | 10 | 8 | 8 | 84 |
| Aug. 11, 1928 | Out | 680 | 1603 | 46 | 44 | 157 | 439 | 15 | 9 | 8 | 83 |
| Aug. 13, 1928 | Out | 602 | 1351 | 35 | 35 | 122 | 382 | 11 | 8 | 8 | 84 |
| Aug. 16, 1928 | Out | 574 | 1276 | 32 | 33 | 111 | ... | .. | .. | .. | .. |
| Aug. 18, 1928 | Out | 907 | 2061 | 64 | 55 | 232 | 578 | 11 | 9 | 8 | 83 |
| Aug. 20, 1928 | Out | 645 | 1451 | 36 | 36 | 139 | 422 | 12 | 7 | 7 | 86 |
| Aug. 23, 1928 | Out | 645 | 1547 | 57 | 49 | 116 | 362 | 10 | 12 | 10 | 78 |
| Aug. 25, 1928 | Out | 829 | 1923 | 60 | 54 | 176 | 515 | 5 | 9 | 9 | 82 |
| Aug. 28, 1928 | Out | 595 | 1362 | 38 | 39 | 122 | 381 | 4 | 8 | 8 | 84 |
| Sept., 1928 | In | 425 | 1118 | 73 | 68 | 81 | 132 | 9 | 27 | 25 | 48 |
| " | Out | 680 | 1545 | 43 | 42 | 148 | 421 | 3 | 8 | 8 | 84 |

| Date of Sample | Water | Chlorine Cl | Total Solids | Calcium Ca | Magnesium Mg | Sulphate $SO_4$ | Sodium Na | Potassium K | Ratio Calcium Ca | Ratio Magnesium Mg | Ratio Sodium Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct., 1928 | In | 422 | 1199 | 70 | 67 | 81 | 132 | 7 | 26 | 25 | 49 |
| " | Out | 680 | 1600 | 53 | 49 | 148 | 404 | 4 | 10 | 9 | 81 |
| Nov., 1928 | In | 400 | 996 | 65 | 63 | 74 | 125 | 9 | 26 | 25 | 49 |
| " | Out | 704 | 1613 | 57 | 53 | 155 | 429 | 6 | 11 | 9 | 80 |
| Dec., 1928 | In | 380 | 902 | 67 | 62 | 74 | 130 | 9 | 26 | 24 | 50 |
| " | Out | 670 | 1500 | 47 | 43 | 146 | 441 | 6 | 9 | 8 | 83 |
| Jan., 1929 | In | 386 | 1041 | 66 | 62 | 75 | 119 | 6 | 26 | 25 | 49 |
| " | Out | 638 | 1490 | 55 | 48 | 135 | 368 | 4 | 12 | 10 | 78 |
| Feb., 1929 | In | 361 | 966 | 61 | 56 | 73 | 128 | 6 | 25 | 23 | 52 |
| " | Out | 645 | 1440 | 48 | 42 | 137 | 403 | 4 | 10 | 8 | 82 |
| Mar., 1929 | In | 347 | 920 | 60 | 54 | 68 | 125 | 10 | 25 | 23 | 52 |
| " | Out | 631 | 1445 | 44 | 43 | 131 | 423 | 10 | 9 | 8 | 83 |
| April, 1929 | In | 387 | 1072 | 64 | 61 | 64 | 116 | .. | 27 | 25 | 48 |
| " | Out | 584 | 1375 | 44 | 42 | 109 | 337 | .. | 10 | 10 | 80 |
| May, 1929 | In | 402 | 1059 | 66 | 63 | 73 | 107 | .. | 28 | 27 | 45 |
| " | Out | 573 | 1327 | 43 | 42 | 101 | 312 | .. | 10 | 10 | 80 |
| June, 1929 | In | 403 | 1086 | 68 | 67 | 75 | 122 | .. | 26 | 26 | 48 |
| " | Out | 594 | 1348 | 43 | 45 | 112 | 355 | .. | 10 | 10 | 80 |

## Field 11

The ratio of calcium in the irrigation water to that in the drainage is very consistent. While in some months there was a lower ratio of calcium to magnesium and sodium in the drainage water, on the whole the calcium was practically the same or slightly higher, which indicates little or no fixation of calcium from the irrigation water. A low calcium ratio would show that the calcium was being retained by the soil. With scarcely a single exception the magnesium ratio has been reduced in passing through the soil, showing a fixation of magnesium, and there should follow from this a progressive increase in zeolite magnesium in the soil. The relative sodium shows a consistently higher ratio in the drainage water. Therefore, zeolite sodium is being steadily reduced, apparently by the magnesium rather than by the calcium. With the soil already high in zeolite magnesium, this can hardly be considered a desirable condition. It is rather significant that there was a slight increase in sodium ratio in December and January following 26 inches of rain in December.

Expressed as parts per million, there has been a wide variation in the calcium, magnesium and sodium content of the drainage water, while the irrigation water remained remarkably constant over the two-year period. In most cases, a greater amount of salt is being drained from D 200, which is the more fertile section of the field and indicates the benefit from salt removal.

In November, 1927, gypsum was applied to several ditches in the area drained by D 200. The effect of the gypsum is indicated in Figs. 3 and 5. These several samples were taken at short intervals following its application. In December, there was an unusually heavy rainfall, and from that time to harvest the concentration of bases in the drainage water was reduced. On the other hand, the daily changes fluctuated very greatly, as shown by the data in Table IV and Figs. 3 and 5.

In July, 1928, ground coral rock was applied at the rate of 9 tons per acre and the field plowed to a depth of 20 inches. From this period there was a steady increase in salt concentration of the drainage water, indicating that this treatment had served to release the salt in larger quantities and at a more rapid rate than previously. It should not be overlooked, however, that the deep plowing alone would have a somewhat similar effect in aiding leaching operations. Since February there has been some reduction from the maximum months of December, 1928, and January, 1929. It is significant that while the concentration of salt has been increased the ratio remained quite steady.

The gypsum, which was applied in the irrigation water from October 20 to 25, 1927, as shown in Fig. 3, has slightly increased the sodium ratio in the drainage.

During November, December and January, individual samples of water were analyzed, in addition to the composite, in order to determine the effect of the unusually heavy rainfall (non-saline water). The effect is of considerable interest. There were two periods of heavy rain, namely, 18.5 inches between December 8 and 13, and 6.1 inches between December 23 and 25. Therefore, less pump water was used during this month. Each period was followed by an increase in salt in

the drainage water and a higher sodium ratio for December and January. An occasional heavy rain appears to increase the sodium ratio in the drainage, but has little or no effect upon the calcium.

## Field 3D

In Field 11, the tile drainage system had been in operation for five years previous to the start of these soil studies, while in Field 3D the field was being cropped for the first time after the installation of the tiles. This is reflected in the high saline content of the drainage water during the first eight months. The Ca:Mg:Na ratio is very similar to the drainage from Field 11 and shows that in this field, also, zeolite sodium is being reduced by base replacement. On the other hand, unlike Field 11, and to better advantage, the calcium as well as the magnesium is being fixed by the zeolite.

An increase in salt content of the drainage started in again with the new crop, as noted by the months August to November, 1928. Also, the salt content was notably reduced by the rains of December, 1927.

In a comparison of the drainage waters from Fields 3D and 11, the better fixation of calcium in the former is significnat. In view of this, the average composition of the irrigation water applied to these two fields was calculated for the two-year period, and the results are given in the following table:

| | Parts per Million | | | Ratio | | |
|---|---|---|---|---|---|---|
| | Ca | Mg | Na | Ca | Mg | Na |
| Field 3D | 68 | 63 | 125 | 27 | 24 | 49 |
| Field 11 | 77 | 76 | 118 | 28 | 29 | 43 |

The pump water being used on Field 3D is, therefore, a slightly better water, having a higher ratio of calcium to magnesium, and this probably accounts for the more effective reclamation taking place in Field 3D. On the other hand, it is recognized that Field 3D was more recently tiled, which may be involved to a certain extent.

In expressing calcium: magnesium ratios by weight or concentration, the fact should not be overlooked that calcium has an atomic weight of 40.07, while that of magnesium is only 24.32. Therefore, the equivalent reaction or replacement value will be 40.07/24.32 or 1.65. That is, one part by weight of magnesium is equivalent to 1.65 parts by weight of calcium. This helps to explain, in part, the antagonism met in replacement operations when waters of nearly equal calcium-magnesium concentration are used. A water containing equal amounts of calcium and magnesium would in reality contain 1.65 as much magnesium on an equivalent basis.

## Field C

Of the three fields under tile drainage, Field C offers an example of a very effective reclamation. As already stated, this field is the closest approach to a bad saline field and contains a high percentage of zeolite sodium, as well as an excessive salt accumulation. The drainage water analyses show a great reduction in

calcium and magnesium as the water leaches through the soil, with a corresponding increase in sodium both as ratio and as concentration in parts per million, which proves beyond question that the zeolite sodium is being steadily and effectively replaced by calcium and magnesium.

On July 14, 1928, calcium chloride was applied to the barren spot in this field at the rate of one ton per acre and then flooded. Drainage water analyses were made at each sampling during the rest of July and throughout August. There is some indication of improvement in the composition of the drainage water, but this is within experimental error and not conclusive. The excellent replacement which is already taking place in this field could hardly be improved upon except in rate. This could be accomplished by more frequent irrigation or flooding, especially if the area were contoured, to force the water to leach down through the bad area rather than through the more permeable area surrounding this barren spot.

Then again, one ton per acre of calcium chloride only furnished about 700 pounds calcium per acre, and the soil contains 26,000 pounds sodium per acre in the three feet of soil above the tiles.

In the preceding interpretations, and in the tables and graphs, no allowance was made for rainfall or variation in amount of water applied to the fields and the volume leaching out through the drains. The application of water varies, of course, with the rainfall and age of the cane. Thus far we have been concerned only with the relative concentration of bases in the ditch water and drainage. In the following tables, VI, VII, VIII, which were compiled and supplied by Mr. Bond, of Ewa Plantation Company, the rainfall, the relative monthly application of pump water and the monthly volume of drainage water for Fields 3D and 11 are given, together with rainfall.

From these data we have calculated the relative amounts of Ca, Mg and Na, which have been applied to the fields and removed in the drainage. These data are shown graphically in Fig. 6, both in pounds and ratio by weight.

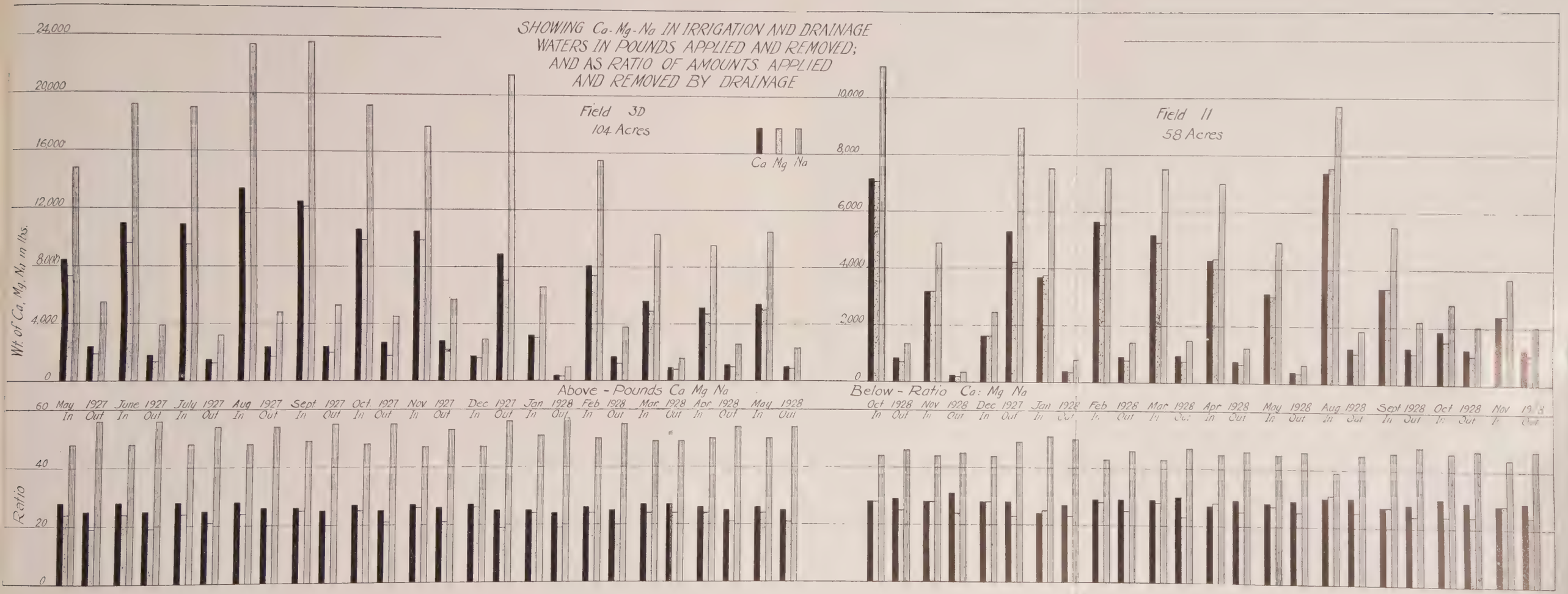
SHOWING Ca-Mg-Na IN IRRIGATION AND DRAINAGE WATERS IN POUNDS APPLIED AND REMOVED; AND AS RATIO OF AMOUNTS APPLIED AND REMOVED BY DRAINAGE
Field 3D
104 Acres
Field 11
58 Acres
Ca Mg Na
Wt of Ca, Mg, Na in lbs.
24,000
20,000
16,000
12,000
8,000
4,000
0
10,000
8,000
6,000
4,000
2,000
0
Above - Pounds Ca Mg Na
Below - Ratio Ca: Mg Na
May 1927 June 1927 July 1927 Aug 1927 Sept 1927 Oct. 1927 Nov 1927 Dec 1927 Jan 1928 Feb 1928 Mar 1928 Apr 1928 May 1928
Oct 1928 Nov 1928 Dec 1927 Jan 1928 Feb 1928 Mar 1928 Apr 1928 May 1928 Aug 1928 Sept 1928 Oct 1928 Nov 19
In Out
Ratio
60
40
20
0

Fig. 6. Showing pounds Ca, Mg and Na in irrigation and drainage waters from Fields 3D and 11.

TABLE VI

Ewa Plantation Company

Field 3D; Crop 1928; Drainage Project; 104.00 Acres

| | Millions of Gallons | | | | Total Water Received | Millions of Gallons Discharge | Per Cent Discharge | Per Cent Discharge Without Rain |
|---|---|---|---|---|---|---|---|---|
| | Irrigation | Sprinkler* | Total | Rain | | | | |
| 1926 | | | | | | | | |
| Dec. | 4.38 | 0.27 | 4.65 | 2.06 | 6.71 | 0.51 | 7.61 | 10.99 |
| 1927 | | | | | | | | |
| Jan. | 5.99 | 0.27 | 6.26 | 5.14 | 11.40 | 0.98 | 8.60 | 15.66 |
| Feb. | 2.91 | 0.20 | 3.11 | 8.95 | 12.06 | 0.50 | 4.14 | 16.06 |
| Mar. | 7.97 | 0.14 | 8.11 | 13.95 | 22.06 | 1.13 | 5.12 | 13.93 |
| April | 5.74 | 0.14 | 5.88 | 6.24 | 12.12 | 0.92 | 7.61 | 15.69 |
| May | 14.24 | 0.34 | 14.58 | 7.74 | 22.32 | 2.10 | 9.41 | 14.41 |
| June | 18.65 | 0.37 | 19.02 | 0.79 | 19.81 | 1.78 | 8.98 | 9.36 |
| July | 18.16 | 0.61 | 18.77 | 0.93 | 19.70 | 1.83 | 9.27 | 9.73 |
| Aug. | 22.63 | 0.48 | 23.11 | 0.23 | 23.34 | 2.42 | 10.35 | 10.45 |
| Sept. | 20.14 | 0.48 | 20.62 | 2.68 | 23.30 | 2.68 | 11.48 | 12.97 |
| Oct. | 17.46 | 0.24 | 17.70 | 1.50 | 19.20 | 2.31 | 12.01 | 13.03 |
| Nov. | 17.74 | 0.23 | 17.97 | 5.51 | 23.48 | 2.99 | 12.73 | 16.62 |
| Dec. | 2.98 | .... | 2.98 | 64.39 | 67.37 | 10.77 | 15.98 | 361.17 |
| 1928 | | | | | | | | |
| Jan. | 6.15 | .... | 6.15 | 0.90 | 7.05 | 0.77 | 10.98 | 12.60 |
| Feb. | 15.29 | 0.17 | 15.46 | 1.72 | 17.18 | 2.94 | 17.11 | 19.02 |
| Mar. | 10.78 | 0.17 | 10.95 | 2.17 | 13.12 | 1.56 | 11.85 | 14.20 |
| April | 8.97 | .... | 8.97 | 4.52 | 13.49 | 2.04 | 15.14 | 22.77 |
| May | 9.15 | 0.10 | 9.25 | .... | 9.25 | 1.78 | 19.29 | 19.29 |
| June | .... | .... | .... | 2.06 | 2.06 | 0.64 | 30.81 | .... |
| | 209.33 | 4.21 | 213.54 | 131.48 | 345.02 | 40.65 | 11.78 | 19.03 |

Field 3D; Crop 1930 1st; Drainage Project; 105.00 Acres

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1928 | | | | | | | | |
| July | 19.13 | 0.31 | 19.44 | 2.71 | 22.15 | 1.44 | 6.50 | 7.41 |
| Aug. | 15.12 | 0.34 | 15.46 | 0.37 | 15.83 | 0.65 | 10.44 | 10.69 |
| Sept. | 14.11 | 0.55 | 14.66 | 0.34 | 15.00 | 1.35 | 9.02 | 9.23 |
| Oct. | 15.84 | 0.72 | 16.56 | 2.59 | 19.15 | 1.83 | 9.55 | 11.54 |
| Nov. | 9.05 | 0.24 | 9.29 | 8.61 | 17.90 | 2.21 | 12.36 | 23.82 |
| Dec. | 8.02 | 0.24 | 8.26 | 2.11 | 10.37 | 1.75 | 16.86 | 21.16 |
| 1929 | | | | | | | | |
| Jan. | 13.78 | 0.24 | 14.02 | 5.70 | 19.72 | 2.53 | 12.85 | 18.07 |
| Feb. | 8.69 | .... | 8.69 | 13.14 | 21.83 | 2.83 | 12.97 | 32.59 |
| Mar. | 15.34 | 0.29 | 15.63 | 0.34 | 15.97 | 2.84 | 17.76 | 18.15 |
| April | 21.25 | 0.73 | 21.98 | 1.71 | 23.69 | 4.22 | 17.80 | 19.19 |
| May | 21.65 | 0.74 | 22.39 | 3.25 | 25.64 | 4.06 | 15.83 | 18.12 |
| June | 22.93 | 0.37 | 23.30 | 0.34 | 23.64 | 3.74 | 15.83 | 16.06 |
| July | 23.53 | 0.64 | 24.17 | 6.68 | 24.85 | 5.38 | 21.67 | 22.28 |

* Overhead Sprinkler System.

TABLE VII

Ewa Plantation Company

Field 11; Crop 1928 Short; Drainage Project; 58.30 Acres Under Drainage

| | Millions of Gallons | | | Discharge in Millions of Gallons | | | | Per Cent Discharge Without Rain |
|---|---|---|---|---|---|---|---|---|
| | Irrigation | Rain | Total | D–100 | D–200 | Total | Per Cent | |
| 1927 | | | | | | | | |
| Feb. | .... | 2.25 | 2.25 | .... | 0.03 | 0.03 | 1.44 | .... |
| Mar. | 5.09 | 7.82 | 12.91 | 0.15 | 1.07 | 1.22 | 9.44 | 23.93 |
| April | 4.60 | 3.50 | 8.10 | 0.12 | 0.55 | 0.67 | 8.26 | 14.55 |
| May | 7.00 | 4.34 | 11.34 | 0.19 | 0.72 | 0.91 | 7.99 | 12.95 |
| June | 9.65 | 0.44 | 10.09 | 0.06 | 0.67 | 0.73 | 7.19 | 7.52 |
| July | 10.66 | 0.52 | 11.18 | 0.14* | 0.54 | 0.68 | 6.03 | 6.33 |
| Aug. | 11.25 | 0.13 | 11.38 | 0.15* | 0.73 | 0.88 | 7.76 | 7.84 |
| Sept. | 11.53 | 2.06 | 13.59 | 0.16 | 0.75 | 0.91 | 6.66 | 7.85 |
| Oct. | 10.60 | 0.78 | 11.38 | 0.08 | 0.73 | 0.81 | 7.18 | 7.71 |
| Nov. | 4.94 | 3.99 | 8.93 | 0.06 | 0.18* | 0.24 | 2.65 | 4.80 |
| Dec. | 2.49 | 33.83 | 36.32 | 1.58 | 3.59 | 5.17 | 14.23 | 207.90 |
| 1928 | | | | | | | | |
| Jan. | 6.49 | 0.49 | 6.98 | 0.09 | 0.53 | 0.62 | 8.97 | 9.64 |
| Feb. | 9.00 | 0.49 | 9.49 | 0.28 | 0.89 | 1.17 | 12.27 | 12.93 |
| Mar. | 8.22 | 1.09 | 9.31 | 0.34 | 0.78 | 1.12 | 12.01 | 13.60 |
| April | 6.80 | 3.21 | 10.01 | 0.05 | 0.86 | 0.91 | 9.01 | 13.26 |
| May | 4.73 | 0.47 | 5.20 | .... | 0.44 | 0.44 | 8.39 | 9.23 |
| June | .... | 0.57 | 0.57 | .... | 0.02 | 0.02 | 4.21 | .... |
| | 113.05 | 65.98 | 179.03 | 3.45 | 13.08 | 16.53 | 9.22 | 14.60 |

Field 11; Crop 1930 Plant; Drainage Project; 61.70 Acres Under Drainage

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1928 | | | | | | | | |
| July | 3.74 | 1.32 | 5.06 | 0.02 | 0.17 | 0.19 | 3.83 | 5.18 |
| Aug. | 11.24 | 0.35 | 11.59 | 0.24 | 0.87 | 1.11 | 9.62 | 9.92 |
| Sept. | 6.42 | 0.01 | 6.43 | 0.22 | 0.64 | 0.86 | 13.52 | 13.52 |
| Oct. | 5.10 | 1.79 | 6.89 | 0.43 | 0.82 | 1.25 | 18.09 | 24.45 |
| Nov. | 2.86 | 4.67 | 7.53 | 0.34 | 0.70 | 1.04 | 13.81 | 36.41 |
| Dec. | 3.88 | 1.46 | 5.34 | 0.16 | 0.69 | 0.85 | 15.90 | 21.87 |
| 1929 | | | | | | | | |
| Jan. | 4.83 | 4.09 | 8.92 | 0.35 | 0.90 | 1.25 | 14.02 | 25.88 |
| Feb. | 2.41 | 5.53 | 7.94 | 0.21 | 1.19 | 1.40 | 17.68 | 58.23 |
| Mar. | 6.73 | 0.13 | 6.86 | 0.30 | 0.93 | 1.23 | 17.94 | 18.30 |
| April | 7.56 | 0.57 | 8.13 | 0.59 | 0.76 | 1.35 | 16.53 | 17.77 |
| May | 11.09 | 1.24 | 12.33 | 0.74 | 1.92 | 2.66 | 21.57 | 23.98 |
| June | 11.70 | 0.20 | 11.90 | 0.80 | 2.00 | 2.80 | 23.50 | 23.91 |
| July | 18.08 | 0.27 | 18.35 | 1.43 | 2.78 | 4.21 | 22.96 | 23.30 |

* Few of the days estimated on account of the sticking of the meters.

TABLE VIII

Monthly Rainfall at Mill

Ewa Plantation Company

| | Year 1927 | Year 1928 | Year 1929 |
|---|---|---|---|
| January | .... | 0.31 | 2.44 |
| February | .... | 0.54 | 3.30 |
| March | .... | 0.69 | 0.08 |
| April | 2.21 | 2.03 | 0.34 |
| May | 2.74 | 0.30 | 1.14 |
| June | 0.28 | 0.36 | 0.12 |
| July | 0.33 | 0.79 | 0.16 |
| August | 0.08 | 0.21 | .... |
| September | 1.30 | 0.03 | .... |
| October | 0.49 | 1.09 | .... |
| November | 2.52 | 2.79 | .... |
| December | 21.37 | 0.87 | .... |

Fig. 6 does not cover the data in total. For Field 3D the period of May, 1927, to May, 1928, was selected, as this includes the heavy rainfall of December, 1927. For Field 11 the period of October, 1927, to November, 1928, was selected, which includes the heavy rainfall of December, 1927, and the period immediately following that at which the field was limed.

*Field 3D:* The heaviest applications of irrigation water were, of course, made during the summer months, and this is reflected in the large amounts of salt applied to the fields at this time. The effect of rainfall is quite significant. May, September, November, and especially December, 1927, all show a salt removal above the average and were high rainfall months, as shown in Table VI. The high removal of salt in December is reflected in a reduction in January. This is an example of the effect of pure water upon saline soils in that permeability will be subsequently retarded unless there is an excess of calcium remaining in the soil solution. In terms of the ratio of actual weight of bases in the drainage, and that in the irrigation water, the comparison is very similar to the concentration ratio, as shown in Fig. 2. Sodium ratio is greater in the drainage water, which is a desirable feature, while calcium and magnesium are being reduced or, in other words, fixed by the soil.

*Field 11:* As in Field 3D, the heavy rainfall of December is reflected in the large amount of bases removed in the drainage during this month. While the sodium is increased, there is no evidence that lime which was applied in June has changed the relative amount of magnesium leached out of the soil. Except for December, the amount of bases in drainage is higher and very constant. In fact, the lack of variation in total amount of calcium, magnesium and sodium leached from the soil following the application of lime, regardless of the amount of irrigation water applied, is remarkably consistent and indicates a better regulated movement of water. On the basis of weight ratio, the relation between calcium, magnesium and sodium is similar to the concentration ratio as given in Fig. 3. Calcium shows little or no reduction, and sodium is apparently being largely replaced by

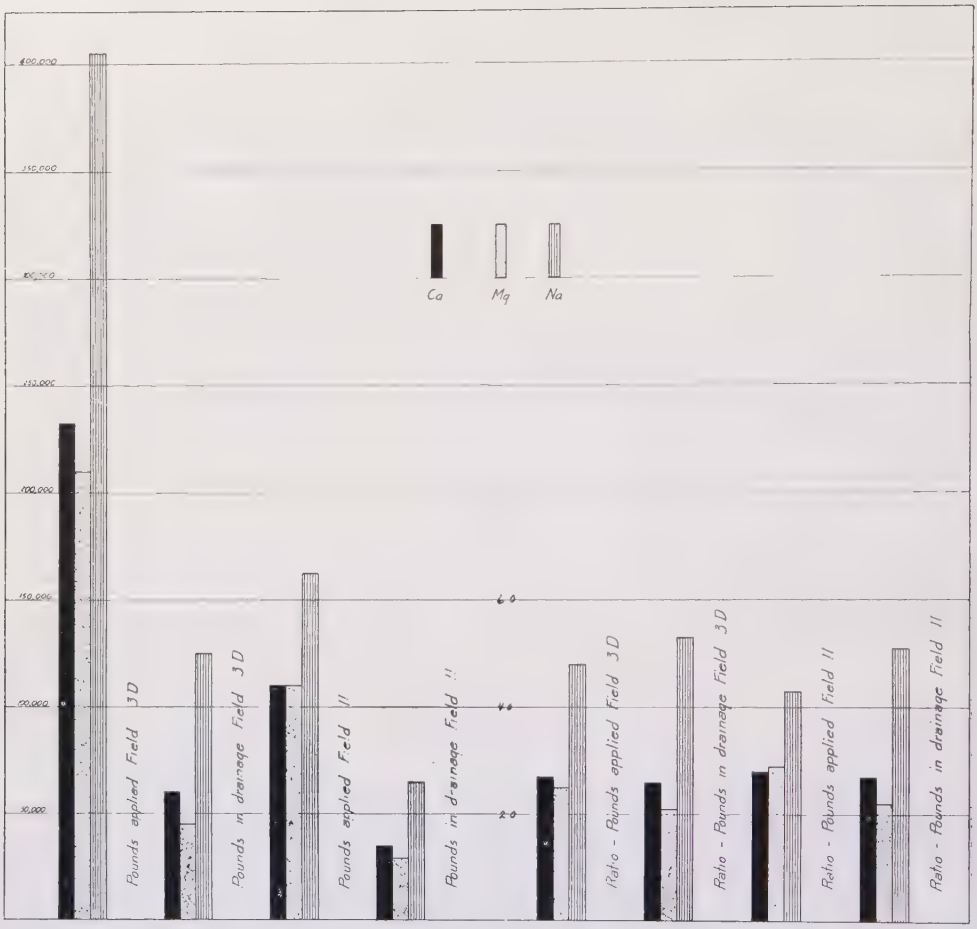
Ca
Mg
Na
Pounds applied Field 3D
Pounds in drainage Field 3D
Pounds applied Field 11
Pounds in drainage Field 11
Ratio - Pounds applied Field 3D
Ratio - Pounds in drainage Field 3D
Ratio - Pounds applied Field 11
Ratio - Pounds in drainage Field 11

**Fig. 7. Showing total Ca, Mg and Na applied and removed. Fields 3D and 11.**

magnesium. There has been little or no change in ratio since liming, indicating that any magnesium which may be replaced by calcium is being precipitated in the lower soil horizons.

We have made no allowance in any of the preceding interpretations for the bases assimilated by the crop, but it is believed that these would be small in proportion to the amounts being applied in the water.

Fig. 7 shows the total amount of the three bases which have been applied to Fields 3D and 11 during the time of the investigation, and the amount removed during this time by the tile drains. As in our previous comparisons, the ratio between the bases is about the same. This figure shows again that either the water being used on Field 3D is more effective or that the tile installation is giving better permeability. It should be mentioned that both fields contain small areas which are not drained by the tiles, and the data in Tables VII and VIII, showing the amount of water applied, cover the field as a whole.

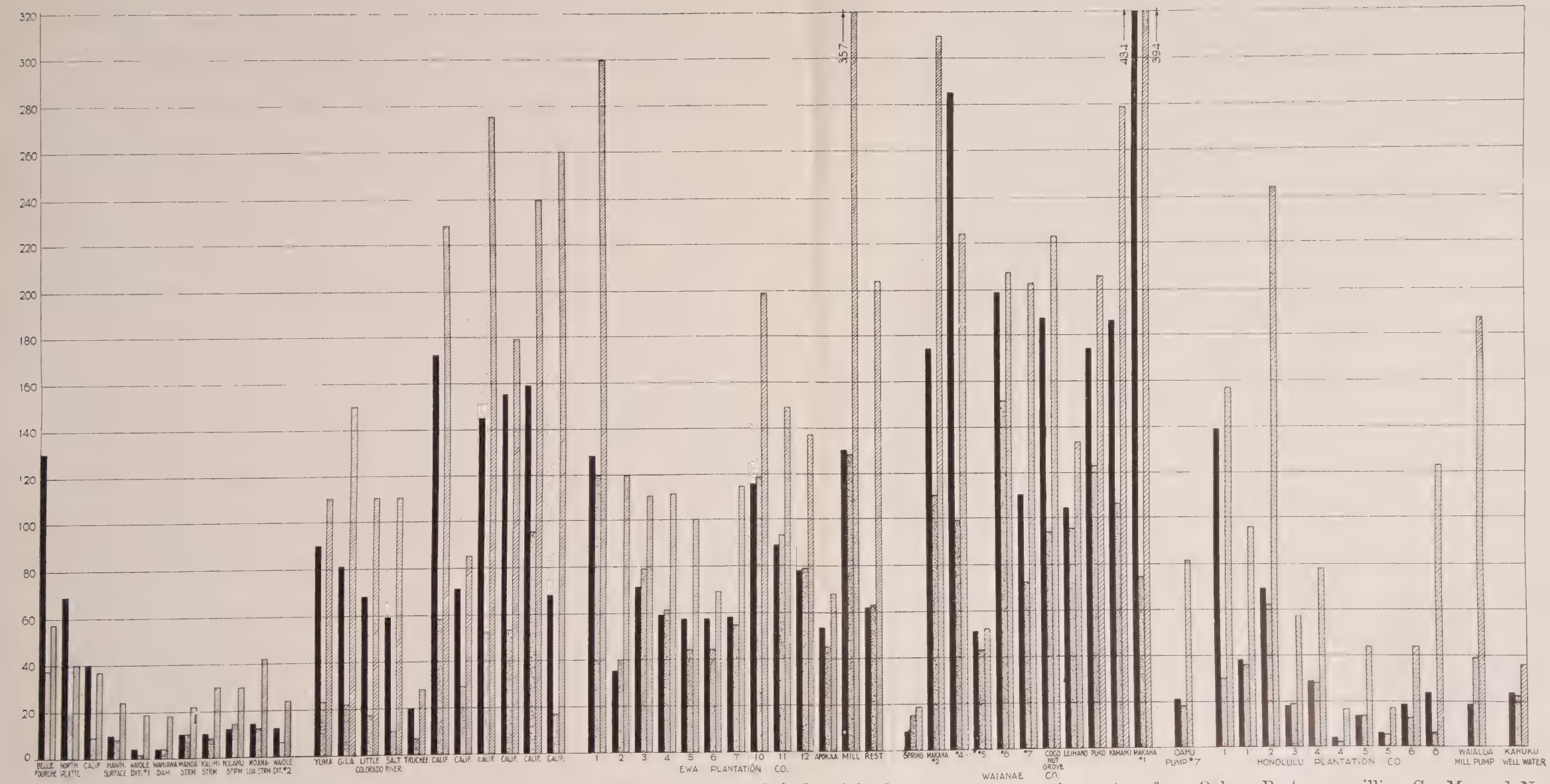


Fig. 8. This figure compares the composition of Ewa irrigation waters with good and bad mainland waters and some other waters from Oahu. Parts per million Ca, Mg and Na. Black—calcium. Shaded—magnesium. Cross-lined—sodium.

## Irrigation Water at Ewa

Considering as a whole the composition of the soil zeolites, the soil solution and the drainage waters from Ewa fields, and the fact that except for 20 inches per annum rainfall the plantation must depend entirely upon the artesian water supply, the present status of Ewa soils is quite good. Where injury to cane growth has occurred it appears to be due to salt accumulation rather than any chemical changes, to date, in the soil character. Where the soils are sufficiently permeable to permit a reasonable rate of water movement there has been little or no saline accumulation and, coincidently little or no injury to cane growth or soil properties. As we have already pointed out, Ewa soils are abnormally high in zeolite magnesium and the relative magnesium content of the irrigation and drainage waters indicates that the magnesium zeolite is progressively increasing. These data, however, do not offer final proof as certain of the magnesium salts are quite unstable and may be precipitating in the soil in some form other than the zeolite. Our data indicate that in Fields 11 and 3D a near equilibrium has been reached between the soil and irrigation water. In view of this, and in view of the lower zeolite sodium as compared with mainland saline types, we sought to compare Ewa irrigation waters, as well as several other Island waters, with those on the mainland.* These comparisons are given in Figs. 8, 9 and 10.

As already stated, the chemical changes in the soil zeolites are in most part a function of the ratio of Ca:Mg:Na in the irrigation water and the difference in the affinity of the zeolite molecule for the respective bases. Keeping this in mind, and comparing our Island waters with mainland waters, the data are quite illuminating. In Figs. 8 and 9 it will be noted that local waters are predominantly high sodium waters, and are not unlike the poor mainland waters in this respect. Even in our mountain streams, Waiahole ditch water and a Waianae spring, while the total salt content is very low, the sodium stands out as the predominant base. On the other hand, in not a single case does the magnesium exceed calcium in mainland waters, while in a number of the Ewa waters it not only exceeds calcium but in practically all samples is relatively higher than mainland waters. Attention is called to the waters on the extreme left of the figure, which have proven excellent for irrigation. They are predominantly high calcium waters. With the exception of several Waianae waters, no other similar types were found among this set of samples, which is fairly representative of the island of Oahu.

The analyses calculated to Ca:Mg:Na ratio are shown graphically in Fig. 9. Referring again to the good mainland waters at the left of the graph, it is significant that the Belle Fourche and North Platte irrigation projects have been remarkably free of alkali troubles. In fact, these two projects, out of the many installed by the U. S. Reclamation Service, stand out prominently for their permeable soils and absence of saline accumulations. This is due to the high ratio of

* Some of these Island waters were analyzed by the writer and other data were taken from the Experiment Station files. The data on California water were taken from some of W. P. Kelley's bulletins. The data on Arizona waters from the Salt River Valley were kindly supplied by P. S. Burgess. The data on other western waters were taken from publications of C. S. Scofield, U. S. Department of Agriculture.

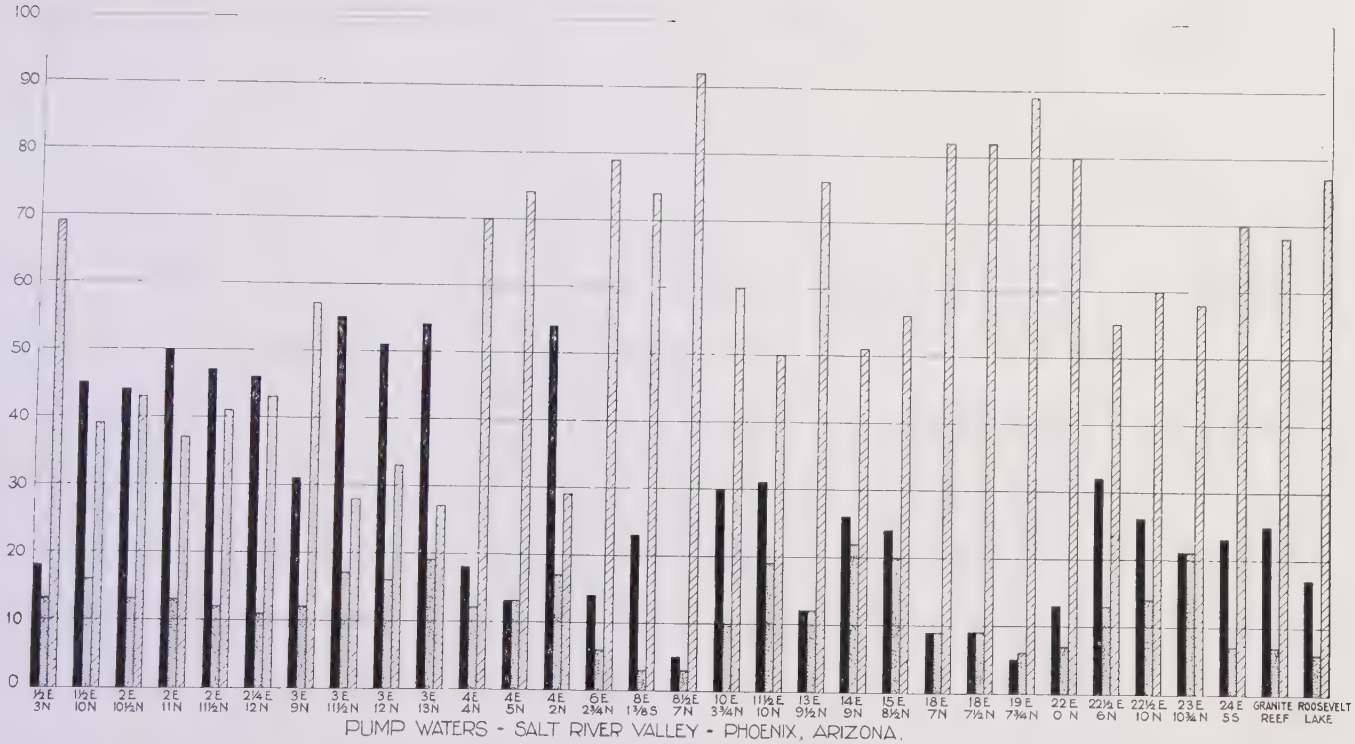


Fig. 10. This figure shows Ca : Mg : Na ratio in pump waters from Arizona. Black—calcium. Shaded—magnesium. Cross-lined—sodium.

calcium in the water. In Fig. 10 some waters from the Salt River Valley in Arizona are shown. A number of these are high-calcium waters, and it is significant that in every case these waters represent sections of the valley which have never been troubled with alkali and, vice versa, the high sodium waters are from sections of the valley where soil troubles have been acute.

Ewa waters have a considerably lower calcium ratio and a higher magnesium ratio than poor mainland waters, while the sodium is about the same. Waianae waters are higher calcium waters, while Honolulu Plantation Company waters are more deficient in calcium than those at Ewa.

We are led to believe from this that since local waters are like poor mainland waters, high in sodium, and our calcium lower than poor mainland waters, the magnesium has been the prime factor in retarding or limiting the fixation of sodium. Furthermore, there is much which leads us to doubt that sodium fixation will ever reach serious proportions at Ewa or any Island soils irrigated with similar waters. In addition to the chemical data which have been presented, other conditions point to the same conclusion. We lack the wide climatic fluctuation of the arid and semi-arid west, namely, a rainy season followed by a hot, dry season during which there is usually very little vegetative growth to shade the soil. There will follow from these conditions an increase in salt content of the surface soil by capillarity and evaporation. Along with the absence of actively growing plants there is an absence of carbon dioxide secretion by roots which, in the form of bicarbonate, would tend to offset injurious effects of alkali. Our cane lands are under continuous cultivation, shaded most of the time and continuously irrigated. Then, too, our humidity is always high. Millar (6) has shown that when no vegetation was present in the field a considerable concentration of salts was noted in the surface one-fourth inch of soil during periods of drought. When the soil supported a growth of vegetation the tendency of salts to accumulate at the surface was largely prevented. A similar condition has been noted by the writer on Island soils (1).

In reclaiming alkali soils an effort is usually made to get alfalfa, an alkali-resistant crop, established as early as possible because the carbon dioxide root secretion, acting as bicarbonate, works for rapidly active and favorably reactive processes, largely as a solvent for calcium. A continuously growing crop is therefore recognized as a means toward staving off acute saline toxicity. If the soil is left unshaded, thus permitting an increase in salines, the less soluble calcium and magnesium will be the first to pass out of solution with an accompanying increase in the undesirable sodium.

There is still another factor which may be involved in that our Island soils are highly basic, and any alkalinity which might be formed by hydrolysis would, in part, react with aluminum and iron.

So we feel safe in concluding that if any difficulties arise they will be due to excess fixation of magnesium rather than sodium.

Gedroiz (7) in his early work on soil zeolites called attention to the high magnesium content of some compact Russian soils, and this has also been noted by

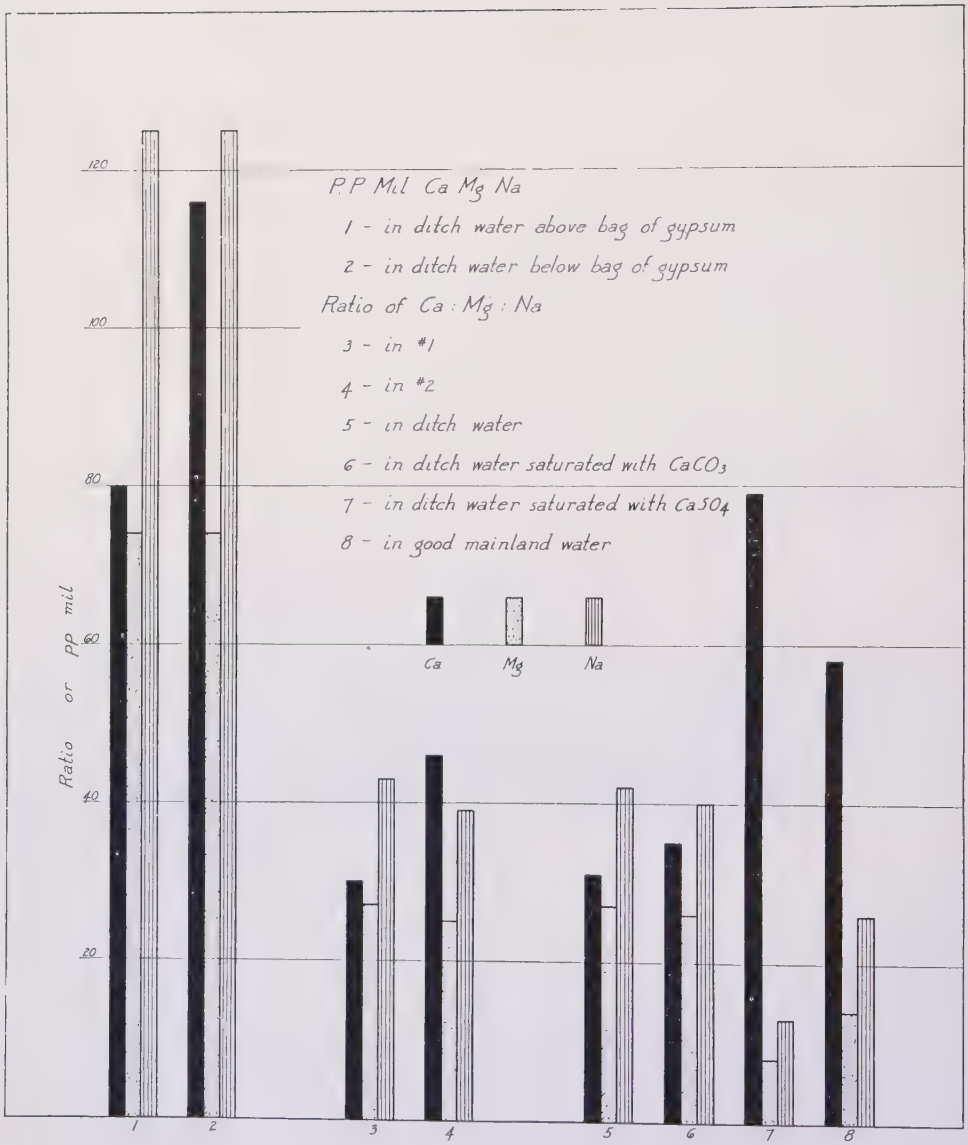


Fig. 11. Showing ratio of Ca : Mg : Na in waters treated with $CaCO_3$ and $CaSO_4$.

Kelley. Page and Williams (8) in England, and Hissink* in Holland, have also noted similar effects from excess magnesium fixation in soils which had been flooded by sea water. Hance (9) found high zeolite magnesium in Maui soils, and he experimentally demonstrated its effect upon soil properties. Gedroiz treated different samples of the same soil with the chlorides of sodium, potassium, magnesium and calcium, obtaining thereby a sodium-clay, a potassium-clay, a magnesium-clay and a calcium-clay. The sodium-clay showed the greatest dispersion; the potassium and magnesium clays similar dispersion but less pronounced, while the calcium-clay was well flocculated. The tendency of clay to remain in a dispersed deflocculated condition is closely associated with the liability of the respective ions to hydrolysis and, as we have already mentioned, this relative tendency between bases is in the order Na>K>Mg>Ca. It is thus evident that to permit an increase in zeolite magnesium, while not so disastrous as sodium, will work for an undesirable dispersed clay in the soil. The result will be a material reduction in permeability, aeration and development of other conditions characteristic of a soil of low fertility.

## Corrective Measures

Knowing the properties of soil zeolites, such as their degree of hydrolysis, effect upon the mechanical condition of the clay and the respective affinity of the zeolite complex for the several common soil bases, it is easy to understand the commanding position which lime holds in the permanency of fertile soils. The proper procedure, therefore, either for preventing magnesium accumulation in Island soils or to reduce the zeolite magnesium in the fields where excessive fixation has taken place, is to use lime in some form.

Increasing the calcium ratio in the irrigation water by means of such materials as gypsum or calcium chloride offers a number of advantages and will reduce fixation and give replacement of both magnesium and sodium. Some experiments along this line were tried both in the laboratory and in the field.

We first conducted several experiments to determine the solubility of carbonate and sulphate of lime in the irrigation water being used in Field 11. This was determined by two methods, as follows: An excess of each was added to two separate bottles each containing two litres of water. The whole was shaken several times a day for one week, then filtered, and calcium, magnesium and sodium determined. As a second experiment, carbonate of lime and gypsum were added and mixed with a column of silica sand and the irrigation water allowed to percolate slowly through the sand. Calcium, magnesium and sodium were determined in this percolate. The solubility by both methods agreed very closely and the data are shown graphically in Fig. 11 as ratio Ca:Mg:Na (6 and 7) as compared with the same water before treatment (5) and a good mainland water (8). It is evident from this that this water may be converted to one of excellent quality by the use of gypsum. To try this out on a field scale, a bag of gypsum, with the side of the bag slit open, was placed in the ditch in such a manner that it was slowly dissolved by the irrigation water, and this treatment continued from October 20 to

* Cited by Page and Williams.

Fig. 12. Showing mechanical state of adobe clay where no coral is present.

Fig. 13. Showing the effect of coral rock on the mechanical condition of adobe clay.

27, 1927. The comparative analyses of the water taken from the ditch above the gypsum and 25 to 50 feet below is shown in Fig. 11 as parts per million (1 and 2), and as ratio (3 and 4). The composition of the drainage water from this section of the field is shown in Fig. 5. The amount of calcium dissolved by the water in passing over the bag of gypsum is far below saturation, but in spite of this there is some evidence of improvement in the composition of the drainage water, all of which shows that increasing the ratio Ca:Mg and Na will effectively control fixation of the other two bases.

As a practical procedure there are certain limitations to such an apparently simple method. Our fields are not uniformly poorly drained. There are scattered areas of widely varying permeability, and an application of calcium in the irrigation water would make less penetration in the areas where it is most needed, being too rapidly drained through the permeable areas. Where such wide variations in soil permeability exist in a field, limestone appears the more feasible procedure.

The heavy black clay which characterizes most of the poorly drained fields at Ewa occurs quite extensively in the lower fields of this Island. We, therefore, sought fields of this soil type which had, during their formation, become mixed with coral rock. Such an area was found in Field 34, a peninsular field at Oahu Sugar Company, and, as we anticipated, the coral had greatly changed the soil to a very friable, mechanical condition, as shown in Figs. 12 and 13. In the former, the heavy soil texture is indicated by the manner in which the soil had caked on drying, while in the latter, the same soil type, the soil is in a good mechanical condition as a result of the coral rock, which is evident in the illustration. Five samples of soil were taken from this field, all representing the same black clay type. Numbers 22 and 23 were taken from opposite sides of the road, 22 being from a coral rock area, and 23 from an area free from coral and badly puddled. Samples 24, 25 and 26 were taken from another section of the same field, 24 and 26 from coral areas, and 25 where no coral was present.

The analyses of these soils are given in Table IX. The zeolite base content is greatly different in the good and bad areas and correlates with the soil texture. This field is in the peninsular section of Oahu Sugar Company and very close to sea level, and there is no question but that if the elevation were sufficiently high to permit good water movement, the zeolite sodium and magnesium would be still further reduced.

TABLE IX

SOILS FROM FIELD 34 OAHU SUGAR CO.

Composition of Soil Solution at 20 Per Cent Moisture Content, Expressed in Parts per Million Soil Solution

| Field | Sample | Sample Depth | Soluble Solids | Calcium Ca | Magnesium Mg | Sodium Na | Potassium K | Sulphate $SO_4$ | Chlorine Cl |
|---|---|---|---|---|---|---|---|---|---|
| 34 | 22 | 0–1 | 4772 | 416 | 128 | 832 | 124 | 832 | 312 |
| 34 | 23 | 0–1 | 6460 | 116 | 28 | 1816 | 208 | 1816 | 961 |
| 34 | 24 | 0–1 | 8948 | 560 | 220 | 1644 | 380 | 2772 | 680 |
| 34 | 25 | 0–1 | 4480 | 44 | 24 | 1192 | 112 | 732 | 824 |
| 34 | 26 | 0–1 | 5904 | 508 | 96 | 1088 | 188 | 1332 | 460 |

Replaceable Bases in Per Cent Dry Soil

| Field | Sample | Sample Depth | Drainage | Reaction pH | Calcium Ca | Magnesium Mg | Sodium Na | Potassium K | Total |
|---|---|---|---|---|---|---|---|---|---|
| 34 | 22 | 0–1 | Good | 8.1 | .706 | .142 | .021 | .085 | .954 |
| 34 | 23 | 0–1 | Poor | 8.0 | .275 | .158 | .192 | .035 | .660 |
| 34 | 24 | 0–1 | Good | 8.0 | .486 | .235 | .075 | .146 | .942 |
| 34 | 25 | 0–1 | Poor | 7.8 | .243 | .144 | .260 | .112 | .759 |
| 34 | 26 | 0–1 | Good | 8.0 | .616 | .059 | .084 | .082 | .841 |

Ratio of Bases to Total, Per Cent of Total

| | | | | | | |
|---|---|---|---|---|---|---|
| | 22 | | | 74.0 | 14.9 | 2.2 | 8.9 |
| | 23 | | | 41.7 | 23.9 | 29.1 | 5.3 |
| | 24 | | | 51.6 | 24.9 | 7.9 | 15.5 |
| | 25 | | | 32.0 | 19.0 | 34.3 | 14.7 |
| | 26 | | | 73.2 | 7.0 | 10.0 | 9.8 |

Replaceable Bases on Milliequivalent Basis (M. E.)

| | | | | | | |
|---|---|---|---|---|---|---|
| | 22 | | | 35.2 | 11.6 | .9 | 2.2 |
| | 23 | | | 13.7 | 12.9 | 8.3 | .9 |
| | 24 | | | 24.2 | 19.3 | 3.2 | 3.7 |
| | 25 | | | 12.1 | 11.8 | 11.2 | 2.8 |
| | 26 | | | 30.7 | 4.8 | 3.6 | 2.1 |

There is, in the above, a natural example of the effect of coral rock, calcium carbonate, upon the mechanical texture and permeability of this black clay type and, incidentally, upon the zeolite magnesium and sodium. This effect of coral rock upon permeability has been further demonstrated in laboratory experiments already published in the *Record* (10). Its effectiveness for the replacement of magnesium is shown in the following experiment:

Two kilograms of soil were placed in each of four large glass percolators. One was leached with distilled water until it became so dispersed and swollen that percolation was completely stopped. The second was leached with ten litres of the same artesian water being used in the field. The third was leached with artesian water after gypsum had been mixed with the surface layer of soil. The fourth was treated in the same manner except that ground coral rock was used instead of gypsum. The soils were then dried, ground and analyzed for zeolite calcium, magnesium, sodium and potassium. The results are given in the following table, together with the same soil, before treatment:

| | Per Cent Calcium Ca | Per Cent Magnesium Mg | Per Cent Sodium Na | Per Cent Potassium K |
|---|---|---|---|---|
| Check—no treatment | .219 | .116 | .047 | .013 |
| Leached with distilled water | .212 | .117 | .051 | .009 |
| Leached with artesian water | .215 | .169 | .043 | .014 |
| Gypsum added to soil | .570 | .103 | .044 | .016 |
| Coral rock added to soil | .385 | .076 | .051 | .014 |

It is evident that leaching with distilled water, the amount we were able to leach through the soil, had little effect upon the zeolite bases. The artesian water has greatly increased the zeolite magnesium, which confirms our field observations. The zeolite magnesium was considerably reduced by the gypsum, but much more effectively by the coral rock.

Field 11 was harvested in June, 1928, and, in view of the fact that the ratoon crop had "gone back" noticeably in the poorer drained areas, the field was plowed and replanted. Ground coral rock, at the rate of 9 tons per acre, was applied before plowing, leaving unlimed areas for comparison, and observation has indicated that there has been a noticeable increase in fertility and cane growth on some of the limed areas. A better permeability is also indicated in the composition of the drainage water beginning with August, 1928, and there is some improvement in the Ca:Mg:Na ratio. Hence, there is plenty of evidence that such Island adobe soil types will be greatly benefited by liming and *that by all means nitrate of lime is the most desirable form of nitrogen to apply to such fields.* It should be mentioned that Field 11 was plowed to a depth of 20 inches, and while we recognize that such a deep plowing would in itself improve the permeability of the soil in this field, we believe that it is in most part due to the lime application.

Breazeale (11) has shown that when calcium carbonate is present in the soil the calcium will react with the magnesium in irrigation water and then enter into base replacement reactions. He found that when calcium chloride and magnesium chloride were added in equivalent amounts to a soil containing both calcium and

magnesium zeolites, no base replacement took place. This is similar to the condition which we have noted in Field 11, except that on an equivalent basis the magnesium is greater than the calcium in the irrigation water. Breazeale has further shown that the calcium present in the soil as calcium carbonate, when dissolved in water that contains carbon dioxide, will replace magnesium from zeolite. This is in accord with our findings.

Calcium carbonate is soluble to 10 parts per million in pure water, will increase in solubility with increase in carbon dioxide content of the water, and may reach a solubility of 1000 parts per million as calcium bicarbonate. Sodium chloride or sodium sulphate, both of which are present in our artesian waters, notably increase the solubility of calcium carbonate. While most calcium salts are less soluble than magnesium salts, this is not true of the hydrate and carbonate. Calcium hydrate is soluble to about 1600 parts per million, while magnesium hydrate is only soluble to 8-10 parts. From this it is evident that calcium carbonate may not only effectively function in base replacement, but also function in precipitating magnesium as carbonate in the soil. The high magnesium present in our coral fields is probably there, in part, as the carbonate as well as the zeolite, and it is difficult to determine the latter in the presence of the former.

The chemical reaction known as base replacement is stimulated or retarded according to the rate or degree of ionization of the zeolite bases, and when ionization is stopped base replacement is no longer possible. For example, Breazeale (11) has shown that a 4 per cent solution of sodium chloride in a saturated solution of gypsum will completely stop replacement of sodium by calcium, if such a solution is used to leach the soil. A 2 per cent solution of potassium chloride will in like manner stop replacement of potassium by calcium. It is evident from this that in a complex salt solution, such as an irrigation water, equilibrium between soil solution and zeolites will continuously vary. If permeability is reduced and salt accumulation permitted, a rising concentration of undesirable bases, such as was found in Field C, for example, may completely stop ionization of the zeolite bases and no replacement will take place until permeability has been restored to the soil.

## Soil Acidity in Poorly Drained Areas

In our discussion of the data in Table II we called attention to the high acidity which had developed in the subsoils of the poorly drained areas. These data, given in terms of pH and specific acidity, are given in the following tabulation:

REACTION AS pH

| | Field 11 | | Field 11 | | Field A | | |
|---|---|---|---|---|---|---|---|
| | Poor | Good | Poor | Good | Poor | Poor | Good |
| First foot | 7.5 | 7.7 | 7.7 | 7.3 | 7.5 | 7.3 | 7.3 |
| Second foot | 6.1 | 7.7 | 6.5 | 7.2 | 5.8 | 5.6 | 7.3 |
| Third foot | 4.8 | 7.5 | 5.3 | 6.0 | 4.7 | 5.3 | 7.2 |
| Fourth foot | ... | ... | ... | ... | ... | 5.1 | ... |

REACTION AS SPECIFIC ACIDITY

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| First foot | 0.32 | 0.19 | 0.19 | 0.50 | 0.32 | 0.50 | 0.50 |
| Second foot | 8.00 | 0.19 | 3.20 | 0.63 | 16.00 | 25.00 | 0.50 |
| Third foot | 160.00 | 0.32 | 50.00 | 10.00 | 250.00 | 50.00 | 0.63 |
| Fourth foot | .... | ... | .... | .... | ..... | 80.00 | ... |

This condition is directly a result of the highly dispersed clay in the soil and its accompanying effect upon soil permeability and aeration. The highly acid subsoils were found only in the poorly drained areas in which aeration has been sufficiently reduced as to injure cane growth. Cane roots *must* have air as well as nutrients in order to properly and effectively function. Likewise, the activities of beneficial organisms are acutely retarded by lack of aeration. In their place another and undesirable soil flora is created, namely, the anaerobic organisms, which create an extremely toxic environment in the root zone. One effect of an active anaerobic soil flora is the development of soil acidity, and this is unquestionably what has taken place in the poor spots in Fields 11 and A. The affinity of the soil zeolite for hydrogen, the acid ion, is so much greater than for the bases that it is rapidly absorbed by the zeolite in spite of the accumulated concentration of the bases calcium, magnesium and sodium in the soil solution. We believe that lime will, in addition to improving permeability, correct this acidity in the subsoils.

Following the harvest of the 1928 crop in Field 11, D. M. Weller, at the request of Mr. Alexander, made root counts in selected poorly drained and well-drained areas in this field. The roots growing in the kuakua and each eight inches of the soil horizon were separated and weighed. At the same time we made analyses of the soils from each horizon. These data were reported by Mr. Alexander in the 1928 Proceedings of the Association of Hawaiian Sugar Technologists, and on account of their significance are reproduced in the following tabulation:

SHOWING ZEOLITE BASES, REACTION AS pH AND WEIGHT OF ROOTS FROM SEVERAL SOIL HORIZONS FROM GOOD AND POOR SPOTS IN FIELD 11

| | Calcium | | Magnesium | | Sodium | | pH | | Wt. of Roots | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Good | Poor | Good | Poor | Good | Poor | Good | Poor | Good | Poor |
| Kuakua | .256 | .201 | .116 | .126 | .016 | .028 | 7.4 | 6.7 | 9.9 | 35.7 |
| First 8 inches | .223 | .204 | .106 | .114 | .016 | .073 | 7.9 | 7.1 | 157.6 | 102.0 |
| Second 8 inches | .136 | .151 | .092 | .086 | .019 | .018 | 7.4 | 6.6 | 40.4 | 3.9 |
| Third 8 inches. | ... | .134 | ... | .088 | ... | .037 | ... | 5.3 | 16.7 | .2 |
| Fourth 8 inches | .121 | .115 | .078 | .088 | .020 | .018 | 5.3 | 4.7 | 2.8 | .1 |
| Fifth 8 inches. | .135 | .083 | .088 | .074 | .020 | ... | 5.7 | 4.8 | .8 | .01 |

These data are extremely significant and serve to emphasize the air requirements of the cane roots. In the poorly drained spot there are practically no roots below eight inches. Ninety-seven per cent of the roots are present in the kuakua and eight inches of surface soil. The improvement in permeability from the tile drains has increased root growth 60 per cent. At the same time there has been an improvement in the zeolite composition, namely, an increase in zeolite calcium and a reduction in zeolite hydrogen, magnesium and sodium, all of which will work progressively for better soil fertility.

## Discussion

The results obtained in this investigation serve to establish a number of significant and important facts regarding the fertility of Ewa soils and can be applied to many other Island areas. None of the Ewa soils closely approach what we would term acute saline conditions. On the other hand, due to either poor drainage, soil texture, or high water table, there has been sufficient salt accumulation in some fields to reduce cane yields. It is significant in this connection that a recent survey of Ewa yields, by Das (12), covering a number of years, has shown that Lahaina failure at Ewa was definitely associated with certain soil types, notably the poorly drained. We have demonstrated the presence of high saline accumulations in such fields and it has been shown that even when Lahaina was at its worst, during the dry years, the cane made excellent growth after a heavy rain. Therefore, the low fertility of the poorly drained fields is not of recent recognition, and within late years has led to the installation of tile drains in several such fields.

The line of investigation which we have pursued has sought to augment our fundamental knowledge of the present condition of Ewa soils beyond a mere accumulation of salts and its physiological effect upon cane growth.

That fraction of clay which is referred to as a zeolite compound lies at the very foundation of most soil properties, both desirable and undesirable. In Ewa soils we find that the sodium present as zeolite, while above the average of a normal soil, is far short of the recognized serious proportion. That this is true, in spite of the fact that high sodium waters are used to irrigate and heavy applications of nitrate of soda have been made over an extensive period of years, is very significant. Only where drainage is very bad has there been any evidence of an increase in zeolite sodium, and this is being effectively reduced by drainage.

On the other hand, there are on this Island a number of scattered areas in which a heavy black clay type of soil exists. It has been found that the zeolite compounds present in this type are in large part, or in excess, combined with magnesium. The clay fraction of the soil when combined with an excess of magnesium will, like sodium, but to a lesser extent, exhibit a high degree of dispersion. In fact, there may even be an increase in the amount of clay in the soil, as shown by Gedroiz. He took a soil containing 39.9 per cent of clay, saturated it with sodium and thereby increased the clay to 59.8 per cent. Soils, then, containing an excess of sodium or magnesium zeolite, will usually be heavy clays and be composed physically of a high percentage of the clay fraction. The heavy clay, magnesium type, is present in a number of Ewa fields and it is characteristically difficult to drain. The irrigation water in use at Ewa, as compared to a wide variety of irrigation waters in use on the mainland, contains an abnormally high magnesium content in proportion to calcium. This high magnesium, together with the calcium, has, in most part, prevented an excessive fixation of sodium as zeolite in Ewa soils. On the other hand, this high magnesium present in the water has limited fixation of calcium, the fixation of which is highly essential in maintaining an optimum soil texture and a permanent soil fertility. At the same time, the magnesium zeolite has increased in some fields, notably where drainage is poor

The problem then resolves itself into a reduction of zeolite magnesium in the poorly drained fields and a prevention of any further accumulation.

We have made rather an exhaustive study of conditions in Fields 11, 3D and C where tile drains have been installed, and the evidence strongly indicates that while the tile drains effectively leach out the excess salt accumulation and lower the zeolite sodium, this practice probably will not reduce the magnesium unless supplemented by some form of calcium.

In areas where this black clay soil is located near coral fields, and along its border it has become merged with the coral soil, the highly dispersed state is entirely changed to one of an excellently flocculated soil. This fact, together with a number of laboratory studies which have been described, shows beyond question that this soil type, even at its worst, will be greatly improved in fertility by liming. Of course, the addition of gypsum or other soluble calcium salt to the irrigation water to increase the calcium ratio of the water, as has been shown, would prove another effective procedure. But most of the areas of this soil type on Oahu are in the makai lands where ground coral rock can be very economically obtained. The freight on gypsum, which must be imported, adds greatly to its cost.

*We believe we have sufficient evidence to conclude that the fertility of poorly drained areas of this black clay type can be effectively improved by liming with ground coral rock and by using nitrate of lime to supply the nitrogen requirements of the crop.*

Both as a matter of prevention, and as a step in the reclamation of lands already gone bad, a great deal of attention on the mainland is being centered on the composition of irrigation water. From a knowledge of the soluble bases and zeolite bases in the soil, and the composition of the irrigation water, it is possible to predict a great deal regarding the cultural possibilities of the land. In some ways, though, the mainland problems are more simple than ours. As a rule, in mainland soils magnesium rarely enters the absorption complex in sufficient quantities to influence its properties. Their problem is confined largely to calcium and sodium, namely, to prevent fixation of the latter or to effect its removal where fixation has become excessive. Zeolite sodium much more disastrously affects soil properties than magnesium but is, on the other hand, more easily replaced by calcium and therefore it is much simpler to prevent sodium fixation than that of magnesium. The fixing power of clay is so much lower for sodium than for calcium or magnesium that unless the former is greatly in excess of the two latter there is not much danger of the clay becoming saturated with sodium. On the other hand, the fixing power of clay for calcium and magnesium is so nearly equal that it becomes a much more difficult problem to control the fixation of magnesium, especially where our irrigation waters are already high in this base. It is not, however, an impossibility.

That the tile drains in Fields 3D and 11 have effectively reduced salt accumulation in these fields is amply proven by the increased cane yields which have followed their installation. Leaching will remove the salts, but unless some special provision is made the leaching process may not bring about the needed change in

zeolites. If a soil contains an excess of sodium or magnesium it will be, in part, toxic to plants even after leaching. Hence the operation should not stop with the leaching, if either of the above conditions exist, as the mechanical condition of the soil will be anything but optimum. In fact, some soil workers maintain that the poorly aerated condition of alkali soils is more toxic than the salts which they contain. The Arabs in the Algerian Oases have for centuries used waters containing 4,000 to 8,000 parts per million salt by the practice of frequent heavy applications and thorough drainage.

That the poorly aerated soil is toxic toward cane roots is amply demonstrated in the root excavation experiment of Alexander and Weller, in Field 11, already cited. This toxic environment is probably due to less leaching in the poor spots. In leaching salts from a field, the water does not penetrate uniformly since a field is rarely of uniform permeability. Some areas may receive water in excess of crop requirements and evaporation losses, while others may not even receive sufficient for crop requirement. There may follow then, in the poorly drained spots, a condition of partial stagnation, due to lack of air and sufficient drainage to refresh the soil solution. In this connection some recent work by Scofield (13) is of interest. In this he has shown that a further necessity for leaching the root zone is important from the standpoint of accumulation of salts rejected by the plant. Of the many inorganic constituents of irrigation water some are used very little by the plant. Crops do not absorb water and dissolved substances in the same proportion that the constituents occur in the soil solution. In his experiments, at the end of 24 days, the residual culture solutions contained 78-91 per cent of the salts originally present. Therefore, he concludes that saline irrigation water must be applied in sufficient quantities, not only to supply the crop needs and meet evaporation losses, but also to leach the root zone and carry away the salts that are left by the water which evaporates from the surface soil or is absorbed by the crop. He says that if waters contain 1,500 to 2,000 parts per million salt, 11 per cent should be allowed for root zone leaching. It will be noted in Tables VI and VII that both Fields 3D and 11 show more than a 10 per cent excess leaching through the tile drains.

In selecting a water for leaching a saline soil, mountain water would probably prove disastrous. The jelly-like property of clay in heavy soils is a direct result of the hydrolysis of sodium or magnesium ions in the zeolite complex, a property only weakly exhibited by calcium. In the presence of an excess of a sodium salt, the hydrolysis of sodium zeolite will be greatly retarded or completely stopped. The same applies to magnesium salts and magnesium zeolite. Under such conditions water should penetrate saline soils, and we know from experience that an excess of salt will flocculate most clays. On the other hand, in the absence of the respective base, or where it is present only in small amounts in the water, hydrolysis becomes active and the clay will swell to clog the intersticial spaces of the soil. Therefore, salt-free water should not be used beyond an initial reduction of salines and, following this, only after a soluble calcium salt has been added to the water. In fact, it may not be out of place to suggest an occasional application of a soluble calcium salt to our mountain water for "hard water makes soft land."

## Summary

1. The nature of the soil zeolite bases in Ewa soils has been determined.

2. Except in a very few poorly drained spots zeolite sodium is not high in spite of the use of high sodium irrigation water.

3. Some Ewa soils contain more than the average zeolite magnesium and these are, on the whole, poorly drained types.

4. Tile drainage has effectively reduced salt accumulation and zeolite sodium, but has not effectively reduced zeolite magnesium.

5. There is some reduction of zeolite magnesium in Field 3D, but little or none in Field 11.

6. Zeolite magnesium can be reduced by gypsum, chloride of lime or ground coral rock.

7. Ewa waters are high magnesium waters and, therefore, when used on heavy clay soils, will work for better fertility if lime in some form is included in the programme of fertilization.

8. All nitrogen applications on the heavy clay types would be better applied as lime nitrate.

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# Annual Synopsis of Mill Data

By W. R. McAllep and W. L. McCleery

Operating data for the year ending September 30, 1929, are presented in this Synopsis. These data represent the production of 907,081 tons of sugar, an increase of approximately 1 per cent over the previous year. While data are included from all factories in the Association, the number has been reduced from 40 to 39 as the Halawa factory is no longer operated.

At 12 factories, the operating year ending September 30 did not coincide exactly with the crop year. These factories are indicated by appropriate marks in the first of the large tables. In ten instances the 1929 crop was not finished when data were transmitted. In five instances portions of the 1928 crop, ground subsequent to September 30, 1928, are included.

Factories are listed in the tables in the order of their average production during the previous five seasons, except where otherwise noted. Operating data, together with averages for the past ten years, are in the first of the large tables. Corresponding averages for all factories except those using the Petree process, or modifications thereof, are in Table No. 3. The second of the large tables contains data on mill settings, etc. Data on cane, chemical control, milling, boiling house work, etc., are presented in a number of small tables and discussed in the text. Data on juice and surface grooving have been omitted as there has been but little change since these were previously included in 1928.

A new large table indicating capacities of factory equipment has been included this year. In a few instances figures in this table are dimensions; all others are calculated to "per ton cane hour," on the basis of rated capacity. Data in this table have been brought up to date by including improvements installed for the 1930 crop.

## Varieties of Cane

Table 1 includes the same five major varieties as in 1928. In comparison with last year, increases are recorded for Yellow Caledonia and D 1135, and decreases for H 109, Yellow Tip and Striped Tip. This is the first decrease which has been recorded for H 109, and the first increase for Yellow Caledonia since 1921. However, according to Acreage Census data, the area planted to Yellow Caledonia is decreasing, and further reductions in the proportion of this variety may be expected. The increase in D 1135, while small in comparison with last season, is moderately large in comparison with 1927. Moderate increases over 1927 are also recorded for Yellow Tip and Striped Tip.

MINOR VARIETIES

One Per Cent or More of the Crop at Any Factory

| | | | |
|---|---|---|---|
| Uba | .71 | K 202 | .16 |
| Striped Mexican | .64 | Rose Bamboo | .15 |
| Lahaina | .57 | U. D. 1 | .12 |
| Badila | .46 | W 4 | .05 |
| H 456 | .36 | W 2 | .04 |
| K 107 | .30 | McBryde 6 | .04 |
| P. O. J. Canes | .26 | D 117 | .03 |
| H 8965 | .19 | K 73 | .03 |

TABLE NO. 1
MAJOR VARIETIES OF CANE
(One per cent or more of total crop)

| | H 109 | Y. C. | D 1135 | Yellow Tip | Striped Tip | Others |
|---|---|---|---|---|---|---|
| H. C. & S. Co. | 99 | .. | .. | .. | .. | 1 |
| Oahu | 88 | .. | 11 | .. | .. | 1 |
| Ewa | 97 | .. | .. | .. | .. | 3 |
| Waialua | 91 | .. | 5 | .. | .. | 4 |
| Maui, Agr. | 86 | .. | .. | .. | .. | 14 |
| Pioneer | 96 | .. | 2 | .. | .. | 2 |
| Olaa | .. | 84 | 16 | .. | .. | .. |
| Lihue | 60 | 1 | 7 | 18 | .. | 14 |
| Haw. Sug. | 84 | 1 | 13 | .. | .. | 2 |
| Honolulu | 100 | .. | .. | .. | .. | .. |
| Onomea | .. | 82 | 5 | 12 | .. | 1 |
| Kekaha | 85 | .. | 5 | .. | .. | 10 |
| Hilo | .. | 88 | 10 | 2 | .. | .. |
| Haw. Agr. | .. | 50 | 37 | .. | .. | 13 |
| Wailuku | 81 | 1 | 5 | .. | .. | 13 |
| Makee | 59 | 15 | .. | 14 | .. | 12 |
| Honokaa | .. | 4 | 73 | .. | .. | 23* |
| Hakalau | .. | 76 | 4 | 20 | .. | .. |
| McBryde | 76 | 3 | 3 | 2 | .. | 16 |
| Laupahoehoe | .. | 36 | 37 | 27 | .. | .. |
| Kahuku | 90 | 10 | .. | .. | .. | .. |
| Hamakua | .. | 24 | 66 | 10 | .. | .. |
| Pepeekeo | .. | 96 | 4 | .. | .. | .. |
| Paauhau | 6 | 1 | 82 | 8 | .. | 3 |
| Koloa | 72 | 2 | .. | 20 | .. | 6 |
| Waiakea | .. | 98 | 1 | .. | .. | 1 |
| Hawi | 1 | .. | 23 | 3 | 64 | 9 |
| Hutchinson | .. | 61 | 31 | .. | .. | 8 |
| Honomu | .. | 89 | 7 | 2 | .. | 2 |
| Kaiwiki | 1 | 20 | 54 | 20 | .. | 5 |
| Waimanalo | 82 | 8 | 8 | .. | .. | 2 |
| Kohala | .. | 1 | 31 | 9 | 32 | 27† |
| Kilauea | 6 | 4 | 4 | 39 | 4 | 43‡ |
| Waianae | 100 | .. | .. | .. | .. | .. |
| Kaeleku | .. | 100 | .. | .. | .. | .. |
| Union Mill | .. | .. | 24 | 1 | 75 | .. |
| Niulii | .. | 15 | 36 | 26 | 23 | .. |
| Waimea | 100 | .. | .. | .. | .. | .. |
| Olowalu | 97 | .. | .. | .. | .. | 3 |
| True Average 1929 | 53.1 | 21.5 | 13.0 | 4.3 | 2.1 | 6.0 |
| " " 1928 | 54.7 | 20.7 | 12.9 | 4.9 | 2.2 | 4.6 |
| " " 1927 | 53.1 | 23.7 | 11.8 | 4.0 | 1.6 | 5.8 |
| " " 1926 | 48.7 | 25.6 | 12.1 | 4.5 | 2.1 | 7.0 |
| " " 1925 | 42.7 | 30.7 | 11.9 | 2.7 | 2.1 | 9.9 |
| " " 1924 | 38.1 | 32.6 | 12.0 | 2.3 | 2.0 | 13.0 |
| " " 1923 | 30.7 | 36.3 | 11.2 | 1.2 | 1.6 | 19.0 |
| " " 1922 | 21.1 | 40.3 | 12.2 | 2.7 | 1.6 | 22.1 |
| " " 1921 | 15.0 | 45.1 | 11.0 | 1.2 | 1.8 | 25.9 |
| " " 1920 | 9.1 | 42.7 | 10.0 | 1.4 | 2.1 | 34.7 |

* Uba, 13%; P. O. J. canes 7%.
† Kohala seedlings.
‡ Uba, 23%; Badila, 15%.

The above tabulation probably includes all or nearly all varieties making up one per cent or more of the crop at any single factory, but it is probable that figures for the ratio of these varieties to the total crop are low in several instances as small amounts of minor varieties are not always reported separately.

The following varie ies, H 8965, McBryde 6, K 73, and the "P. O. J. canes," are included in this classification for the first time.

## Quality of Cane

The quality of cane, as indicated by "quality ratio," is better than in 1927 and 1928, but poorer than in other previous years except 1923, when an identical quality ratio, 8.57, was recorded. Fiber is slightly higher than in the two previous seasons, but lower than in other seasons since 1919.

On Maui the quality ratio is better than in any season since 1920. Formerly low fiber was an outstanding characteristic of Maui cane; now the fiber is higher than on any other island. All factories on Maui report increases in fiber and all except Olowalu reported increases in 1928.

On Oahu quality ratio and also pol. are better than in any year since 1925, and the first expressed juice purity is better than in any year since 1915. Although fiber is slightly higher than last year, it is lower than on any other island.

On Kauai and Hawaii quality ratio, pol. and first expressed juice purity are all better than in the past two seasons. Fiber has decreased slightly.

The islands rank in the usual order on the basis of cane quality, that is, Maui, Oahu, Kauai, and Hawaii.

## Chemical Control

Data for sucrose recovery on available and molasses produced on theoretical are in Tables 4 and 5. Gravity solids and sucrose balances are in Table 6. Data in these tables are useful for detecting avoidable losses and for checking the accuracy of the chemical control. These tables have been continued in recent Synopses largely for the purpose of studying chemical control as applied to factory operation. With improvements in factory operation in recent years the influence of discrepancies in our control methods has become more apparent. While the effect of these discrepancies is not known exactly, and, indeed, may vary somewhat under different conditions, we do know that the calculated figure for available sucrose is too low. Likewise the calculated theoretical amount of molasses is too high. These factors must be taken into consideration when interpreting factory control figures and in examining control data for errors in the application of chemical control methods.

Figures in Tables 4 and 5 indicate that the tendency toward reporting higher recoveries on available is continuing. One factory only has reported under 97 per cent against 3 so reporting last season. On the pol. basis (Table 4) 28 factories report 100 per cent or over, against a previous maximum of 26, and 11 factories report over 101 per cent against a previous maximum of 10. On the sucrose basis (Table 5) 15 factories report 100 per cent or over, against a previous maximum of 13, and two factories report over 101 per cent, the same number as last year. After

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

| | Hawaii | Maui | Oahu | Kauai | Whole Group |
|---|---|---|---|---|---|
| 1920 | | | | | |
| Pol | 12.86 | 15.29 | 13.75 | 13.07 | 13.64 |
| Per cent Fiber | 13.36 | 11.39 | 12.65 | 12.72 | 12.64 |
| Purity 1st Expressed Juice | 87.87 | 88.94 | 85.40 | 86.52 | 87.24 |
| Quality Ratio | 8.45 | 7.08 | 8.07 | 8.28 | 8.00 |
| 1921 | | | | | |
| Pol | 12.25 | 14.67 | 13.72 | 12.67 | 13.12 |
| Per cent Fiber | 13.28 | 11.82 | 12.40 | 13.28 | 12.80 |
| Purity 1st Expressed Juice | 87.18 | 87.37 | 85.46 | 84.07 | 86.22 |
| Quality Ratio | 8.98 | 7.51 | 8.11 | 8.76 | 8.41 |
| 1922 | | | | | |
| Pol | 12.07 | 13.95 | 13.61 | 13.03 | 12.97 |
| Per cent Fiber | 13.16 | 12.38 | 12.88 | 13.22 | 12.95 |
| Purity 1st Expressed Juice | 87.17 | 87.88 | 86.18 | 85.80 | 86.84 |
| Quality Ratio | 9.19 | 7.75 | 8.04 | 8.36 | 8.45 |
| 1923 | | | | | |
| Pol | 12.09 | 13.61 | 12.99 | 12.94 | 12.78 |
| Per cent Fiber | 13.14 | 12.01 | 12.86 | 12.99 | 12.82 |
| Purity 1st Expressed Juice | 87.61 | 88.65 | 85.52 | 86.58 | 87.05 |
| Quality Ratio | 9.12 | 7.91 | 8.50 | 8.42 | 8.57 |
| 1924 | | | | | |
| Pol | 12.44 | 14.34 | 13.48 | 13.34 | 13.26 |
| Per cent Fiber | 12.99 | 12.16 | 12.72 | 12.94 | 12.74 |
| Purity 1st Expressed Juice | 87.98 | 89.19 | 87.02 | 87.31 | 87.86 |
| Quality Ratio | 8.86 | 7.58 | 8.16 | 8.12 | 8.25 |
| 1925 | | | | | |
| Pol | 12.35 | 14.42 | 13.52 | 13.24 | 13.22 |
| Per cent Fiber | 12.92 | 12.40 | 12.60 | 12.91 | 12.74 |
| Purity 1st Expressed Juice | 88.02 | 89.36 | 87.11 | 87.19 | 87.92 |
| Quality Ratio | 8.92 | 7.47 | 8.18 | 8.21 | 8.28 |
| 1926 | | | | | |
| Pol | 12.53 | 14.66 | 13.40 | 13.03 | 13.24 |
| Per cent Fiber | 12.90 | 12.24 | 12.72 | 12.46 | 12.65 |
| Purity 1st Expressed Juice | 87.59 | 89.03 | 86.61 | 86.68 | 87.45 |
| Quality Ratio | 8.80 | 7.40 | 8.29 | 8.39 | 8.30 |
| 1927 | | | | | |
| Pol | 11.34 | 14.00 | 12.61 | 12.07 | 12.32 |
| Per cent Fiber | 12.84 | 11.98 | 12.29 | 12.65 | 12.49 |
| Purity 1st Expressed Juice | 86.27 | 87.85 | 85.87 | 85.17 | 86.28 |
| Quality Ratio | 9.81 | 7.76 | 8.86 | 9.19 | 8.99 |
| 1928 | | | | | |
| Pol | 11.57 | 14.13 | 13.09 | 12.09 | 12.55 |
| Per cent Fiber | 12.58 | 12.56 | 12.13 | 12.82 | 12.50 |
| Purity 1st Expressed Juice | 86.60 | 88.76 | 86.84 | 85.16 | 86.84 |
| Quality Ratio | 9.62 | 7.60 | 8.45 | 9.19 | 8.79 |
| 1929 | | | | | |
| Pol | 11.80 | 14.56 | 13.49 | 12.64 | 12.90 |
| Per cent Fiber | 12.53 | 13.24 | 12.28 | 12.61 | 12.62 |
| Purity 1st Expressed Juice | 86.65 | 89.14 | 87.17 | 85.97 | 87.18 |
| Quality Ratio | 9.53 | 7.39 | 8.20 | 8.76 | 8.57 |

TABLE NO. 3

True Averages of All Factories Except Those Using the Petree Process

| | 1924 | 1925 | 1926 | 1927 | 1928 | 1929 |
|---|---|---|---|---|---|---|
| Cane— | | | | | | |
| Pol | 13.08 | 12.99 | 12.99 | 12.05 | 12.30 | 12.63 |
| Fiber | 12.82 | 12.80 | 12.71 | 12.55 | 12.47 | 12.54 |
| Tons per ton sugar | 8.40 | 8.45 | 8.50 | 9.24 | 9.03 | 8.75 |
| Bagasse— | | | | | | |
| Pol | 1.52 | 1.54 | 1.58 | 1.50 | 1.53 | 1.55 |
| Moisture | 41.26 | 41.25 | 41.09 | 41.61 | 41.36 | 41.46 |
| Fiber | 56.74 | 56.55 | 56.64 | 56.20 | 56.42 | 56.31 |
| Pol % cane | 0.34 | 0.35 | 0.35 | 0.33 | 0.34 | 0.34 |
| Pol % pol of cane | 2.63 | 2.69 | 2.73 | 2.77 | 2.76 | 2.72 |
| Milling loss | 2.68 | 2.73 | 2.79 | 2.66 | 2.72 | 2.74 |
| Weight % cane | 22.59 | 22.63 | 22.44 | 22.33 | 22.11 | 22.26 |
| First Expressed Juice— | | | | | | |
| Brix | 18.34 | 18.14 | 18.24 | 17.17 | 17.45 | 17.76 |
| Pol | 16.07 | 15.91 | 15.88 | 14.74 | 15.08 | 15.40 |
| Purity | 87.61 | 87.67 | 87.05 | 85.84 | 86.41 | 86.69 |
| "Java ratio" | 81.4 | 81.7 | 81.8 | 81.7 | 81.6 | 82.1 |
| Mixed Juice— | | | | | | |
| Brix | 13.37 | 13.44 | 13.65 | 12.88 | 13.04 | 13.29 |
| Pol | 11.31 | 11.38 | 11.48 | 10.67 | 10.89 | 11.15 |
| Purity | 84.56 | 84.67 | 84.12 | 82.88 | 83.47 | 83.89 |
| Weight % cane | 112.66 | 111.03 | 110.10 | 109.71 | 109.87 | 110.18 |
| Pol % cane | 12.74 | 12.64 | 12.64 | 11.71 | 11.96 | 12.29 |
| Extraction | 97.37 | 97.31 | 97.27 | 97.23 | 97.24 | 97.28 |
| Extraction ratio | 20.5 | 21.0 | 21.5 | 22.1 | 22.1 | 21.7 |
| Last Expressed Juice— | | | | | | |
| Pol | 1.84 | 1.90 | 2.06 | 1.88 | 1.94 | 1.99 |
| Purity | 71.73 | 69.63 | 68.72 | 67.76 | 68.39 | 68.73 |
| Maceration % cane | 35.30 | 33.66 | 32.54 | 32.04 | 31.99 | 32.44 |
| Syrup— | | | | | | |
| Brix | 63.18 | 63.63 | 64.21 | 62 91 | 63.05 | 63.38 |
| Purity | 86.02 | 85.95 | 85.49 | 84.54 | 84.86 | 85.24 |
| Increase in purity | 1.46 | 1.28 | 1.37 | 1.66 | 1.39 | 1.35 |
| Lbs. avail. CaO per ton cane | 1.72 | 1.56 | 1.66 | 1.52 | 1.46 | 1.38 |
| Press Cake— | | | | | | |
| Pol | 2.16 | 2.17 | 2.49 | 2.22 | 2.34 | 2.27 |
| Weight % cane | 2.45 | 2.45 | 2.63 | 2.67 | 2.87 | 2.87 |
| Pol % cane | 0.05 | 0.05 | 0.07 | 0.06 | 0.07 | 0.07 |
| Pol % pol of cane | 0.40 | 0.41 | 0.50 | 0.49 | 0.55 | 0.52 |
| Commercial Sugar— | | | | | | |
| Pol | 97.20 | 97.23 | 97.29 | 97.40 | 97.49 | 97.64 |
| Moisture | 0.73 | 0.74 | 0.66 | 0.64 | 0.62 | 0.58 |
| Weight % cane | 11.91 | 11.83 | 11.77 | 10.83 | 11.08 | 11.43 |
| Pol % cane | 11.58 | 11.50 | 11.45 | 10.55 | 10.80 | 11.16 |
| Pol % pol of cane | 88.76 | 88.78 | 88.41 | 87.96 | 88.21 | 88.59 |
| Pol % pol of juice | 91.16 | 91.24 | 90.95 | 90.45 | 90.70 | 91.06 |
| Deterioration factor | 0.26 | 0.27 | 0.24 | 0.25 | 0.25 | 0.25 |
| Final Molasses— | | | | | | |
| Weight % cane | 2.83 | 2.82 | 2.94 | 3.02 | 2.97 | 2.98 |
| Sucrose % cane | 0.97 | 0.93 | 0.99 | 1.01 | 0.98 | 0.98 |
| Sucrose % pol of cane | 7.45 | 7.20 | 7.63 | 8.37 | 8.00 | 7.77 |
| Sucrose % pol of juice | 7.65 | 7.40 | 7.84 | 8.60 | 8.22 | 7.98 |
| Gravity solids | 89.08 | 90.09 | 89.59 | 89.43 | 88.77 | 88.82 |
| Gravity purity | 37.81 | 36.97 | 37.62 | 37.40 | 37.41 | 37.13 |
| Undetermined Losses— | | | | | | |
| Pol % cane | 0.14 | 0.16 | 0.13 | 0.11 | 0.11 | 0.09 |
| Pol % pol of cane | 0.76 | 0.92 | 0.73 | 0.41 | 0.48 | 0.40 |

careful study of these data and chemical control methods, together with observations in factory practice during a number of years, it is apparent that figures for "recovery on available" slightly in excess of 100 per cent, even on a sucrose basis, are not necessarily inconsistent, nor are they necessarily due to errors in the application of our factory control methods. There is little question but that this tendency toward higher figures for recovery on available reflects improvement in boiling house work.

Figures in Table 4 for molasses produced on theoretical are based on the assumption that gravity solids in syrup minus gravity solids in the commercial sugar should be accounted for in the final molasses. The arithmetical average of figures for molasses per cent theoretical in Table 4 is 89.9%. The average for the past seven seasons is 90.2; averages for these seasons varying between a minimum of 88.6 and a maximum of 91.2.

Molasses figures in Table 5 are calculated from sucrose data, using the s. j. m. formula. The average on this basis is 89.1 and the average for the past 4 years 89.6. So far as we can infer from these averages, discrepancies in control methods result in a calculated theoretical figure some 10 per cent too high. While the influence of these discrepancies may vary more or less at individual factories, it seems reasonable to assume tentatively that a range of 5.0 on each side of the above average on the s. j. m. formula basis, of 89.6, should include all accurate figures; that figures above this range indicate the probability of control errors or inversion losses, and figures below this range, control errors or undetermined loss of solids. Ten factories listed in Table 5 are outside of this range: Olaa, Honolulu, Haw. Agr., Makee and Koloa being above, while Lihue, Hilo, Waiakea, Waimanalo, and Olowalu are below.

Gravity solids and sucrose balances for factories reporting on a sucrose basis are in Table 6. Small negative undetermined losses of sucrose are recorded for two factories. No negative undetermined losses of solids are reported.

Table 7 is a compilation of sucrose data. Two additional factories have reported sucrose data this year, bringing the total number so reporting to 33. These factories produce 96 per cent of the crop.

As figures for undetermined loss based on pol. are lower than the actual undetermined loss, it is of interest to determine what correction should be applied to averages for undetermined loss in the large table to arrive at an approximately correct figure. In the following comparison, figures tabulated under "sucrose basis" are averages from Table 7. Figures under "pol. basis" are averages for the same factories included in the "sucrose basis" column.

UNDETERMINED LOSS

| Year | Sucrose Basis | Pol. Basis | Difference |
|---|---|---|---|
| 1926 | 1.20 | .36 | .84 |
| 1927 | 1.13 | .26 | .87 |
| 1928 | 1.21 | .28 | .93 |
| 1929 | 1.05 | .18 | .87 |
| Average | | | .88 |

TABLE NO. 4

APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent pol actually obtained.

| Factory | Available* | Obtained | Recovery on Available | Molasses Produced on Theoretical† |
|---|---|---|---|---|
| H. C. & S. Co. | 94.63 | 95.72 | 101.2 | 94.0 |
| Oahu | 91.16 | 93.33 | 102.4 | 91.2 |
| Ewa | 92.09 | 92.15 | 100.1 | 87.7 |
| Waialua | 92.18 | 92.14 | 100.0 | 88.0 |
| Maui Agr. | 93.52 | 94.82 | 101.4 | 92.3 |
| Pioneer | 92.31 | 92.42 | 100.1 | 87.4 |
| Olaa | 91.27 | 90.24 | 98.9 | 101.2 |
| Lihue | 90.15 | 91.08 | 101.0 | 81.2 |
| Haw. Sug. | 93.23 | 94.43 | 101.3 | 95.1 |
| Honolulu | 92.05 | 91.26 | 99.1 | 91.1 |
| Onomea | 91.44 | 91.96 | 100.6 | 92.4 |
| Kekaha | 91.25 | 91.50 | 100.3 | 86.2 |
| Hilo | 92.40 | 91.62 | 99.2 | 81.4 |
| Haw. Agr. | 90.47 | 90.19 | 99.7 | 92.2 |
| Wailuku | 91.44 | 91.91 | 100.5 | 93.3 |
| Makee | 87.82 | 87.97 | 100.2 | 93.3 |
| Honokaa | 89.56 | 89.88 | 100.4 | 91.7 |
| Hakalau | 92.14 | 93.02 | 101.0 | 89.4 |
| McBryde | 91.64 | 92.71 | 101.2 | 92.2 |
| Laupahoehoe | 92.84 | 91.45 | 98.5 | 85.3 |
| Kahuku | 91.20 | 93.91 | 103.0 | 91.6 |
| Hamakua | 92.89 | 93.86 | 101.0 | 89.0 |
| Pepeekeo | 92.81 | 92.85 | 100.0 | 90.2 |
| Paauhau | 89.80 | 90.08 | 100.3 | 85.3 |
| Koloa | 90.98 | 92.42 | 101.6 | 100.1 |
| Waiakea | 89.37 | 89.02 | 99.6 | 80.1 |
| Hawi | 89.03 | 89.49 | 100.5 | 95.1 |
| Hutchinson | 91.84 | 92.81 | 101.1 | 88.6 |
| Honomu | 92.52 | 93.00 | 100.5 | 94.1 |
| Kaiwiki | 90.06 | 90.43 | 100.4 | 93.3 |
| Waimanalo | 88.80 | 90.27 | 101.7 | 85.1 |
| Kohala | 90.03 | 90.79 | 100.8 | 85 9 |
| Kilauea | 83.96 | 83.49 | 99.4 | 86.9 |
| Waianae | 90.84 | 89.67 | 98.7 | 81.7 |
| Kaeleku | 88.66 | 88.23 | 99.5 | 81.6 |
| Union Mill | 88.31 | 89.84 | 101.7 | ... |
| Niulii | 85.23 | 87.32 | 102.5 | ... |
| Waimea | 91.51 | 84.99 | 92.9 | ... |
| Olowalu | 88.13 | 85.72 | 97.3 | 74.5 |

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When moisture in sugar has not been reported, the moisture corresponding to 0.25 deterioration factor has been used. 38 has been used when the gravity purity of the molasses has not been reported.

† Gravity solids in syrup, less solids accounted for in commercial sugar considered as theoretical gravity solids in final molasses.

TABLE NO. 5

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

| Factory | Available | Obtained | % Recovery on Available | Molasses Produced on Theoretical* |
|---|---|---|---|---|
| H. C. & S. Co. | 94.64 | 95.11 | 100.5 | 90.5 |
| Oahu | 91.28 | 92.22 | 101.0 | 85.0 |
| Ewa | 92.22 | 91.08 | 98.8 | 90.2 |
| Waialua | 92.30 | 90.49 | 98.0 | 90.0 |
| Maui Agr | 93.51 | 94.29 | 100.8 | 88.6 |
| Pioneer | 92.35 | 91.53 | 99.1 | 89.1 |
| Olaa | 90.76 | 89.93 | 99.1 | 101.6 |
| Lihue | 90.35 | 89.89 | 99.5 | 80.7 |
| Haw. Sug | 93.23 | 93.73 | 100.5 | 91.4 |
| Honolulu | 92.35 | 89.67 | 97.1 | 100.7 |
| Onomea | 91.34 | 91.66 | 100.4 | 91.7 |
| Kekaha | 91.18 | 91.26 | 100.1 | 86.6 |
| Hilo | 92.15 | 91.36 | 99.1 | 83.7 |
| Haw. Agr. | 90.61 | 89.38 | 98.6 | 96.6 |
| Wailuku | 91.55 | 91.20 | 99.6 | 93.8 |
| Makee | 88.18 | 86.43 | 98.0 | 95.9 |
| Honokaa | 89.59 | 89.42 | 99.8 | 92.1 |
| Hakalau | 92.28 | 92.40 | 100.1 | 89.8 |
| McBryde | 91.70 | 91.81 | 100.1 | 90.5 |
| Laupahoehoe | 92.72 | 91.16 | 98.3 | 91.9 |
| Kahuku | 91.47 | 92.60 | 101.2 | 86.2 |
| Hamakua | 92.87 | 93.45 | 100.6 | 87.1 |
| Pepeekeo | 92.77 | 92.61 | 99.8 | 92.0 |
| Paauhau | 89.80 | 89.45 | 99.6 | 85.7 |
| Koloa | 91.17 | 91.45 | 100.3 | 98.1 |
| Waiakea | 89.53 | 88.20 | 98.5 | 83.8 |
| Hutchinson | 91.72 | 92.43 | 100.8 | 85.9 |
| Honomu | 92.33 | 92.88 | 100.6 | 92.4 |
| Waimanalo | 88.72 | 89.73 | 101.1 | 81.5 |
| Kohala | 90.04 | 90.30 | 100.3 | 84.9 |
| Kilauea | 84.02 | 82.55 | 98.3 | 87.5 |
| Waianae | 90.97 | 88.92 | 97.7 | 86.7 |
| Olowalu | 88.03 | 85.38 | 97.0 | 80.5 |

* Calculated by the S. J. M. formula.

## GRAVITY SOLIDS AND SUCROSE BALANCES

| Factory | GRAVITY SOLIDS PER 100 GRAVITY SOLIDS IN MIXED JUICE | | | | SUCROSE PER 100 SUCROSE IN MIXED JUICE | | | |
|---|---|---|---|---|---|---|---|---|
| | Press Cake | Commercial Sugar | Final Molasses | Undetermined | Press Cake | Commercial Sugar | Final Molasses | Undetermined |
| H. C. & S. Co. | 3.2 | 84.4 | 11.6 | 0.8 | 0.43 | 94.70 | 4.85 | 0.02 |
| Oahu | 5.1 | 77.3 | 15.7 | 1.9 | 0.61 | 91.66 | 7.41 | 0.32 |
| Ewa | 5.6 | 75.1 | 16.7 | 2.6 | 0.46 | 90.66 | 7.02 | 1.86 |
| Waialua | 3.6 | 77.6 | 15.6 | 3.2 | 0.87 | 89.70 | 6.93 | 2.50 |
| Maui Agr. | ... | 84.8 | 14.0 | 1.2 | .... | 94.29 | 5.75 | —0.04 |
| Pioneer | 4.5 | 76.6 | 16.3 | 2.6 | 0.36 | 91.20 | 6.82 | 1.62 |
| Olaa | 10.2 | 71.2 | 18.5 | 0.1 | 1.17 | 88.88 | 9.39 | 0.56 |
| Lihue | 4.0 | 74.3 | 17.3 | 4.4 | 0.42 | 89.51 | 7.79 | 2.28 |
| Haw. Sug | 4.6 | 79.9 | 14.6 | 0.9 | 0.28 | 93.47 | 6.19 | 0.06 |
| Honolulu | 4.8 | 75.6 | 17.5 | 2.1 | 0.36 | 89.35 | 7.70 | 2.59 |
| Onomea | 3.7 | 76.7 | 18.2 | 1.4 | 0.16 | 91.51 | 7.94 | 0.39 |
| Kekaha | 4.5 | 76.0 | 17.0 | 2.5 | 0.44 | 90.86 | 7.64 | 1.06 |
| Hilo | 5.2 | 76.3 | 15.0 | 3.5 | 0.35 | 91.04 | 6.57 | 2.04 |
| Haw. Agr. | 3.3 | 76.1 | 18.9 | 1.7 | 0.25 | 89.16 | 9.07 | 1.52 |
| Wailuku | 5.7 | 76.4 | 16.6 | 1.3 | 0.59 | 90.66 | 7.92 | 0.83 |
| Makee | 4.4 | 68.7 | 24.6 | 2.3 | 0.59 | 85.92 | 11.33 | 2.16 |
| Honokaa | 6.0 | 71.9 | 20.4 | 1.7 | 0.68 | 88.81 | 9.59 | 0.92 |
| Hakalau | 3.6 | 78.0 | 16.6 | 1.8 | 0.15 | 92.26 | 6.93 | 0.66 |
| McBryde | 3.2 | 77.0 | 18.1 | 1.7 | 0.53 | 91.32 | 7.51 | 0.64 |
| Laupahoehoe | 3.3 | 77.9 | 16.1 | 2.7 | 0.15 | 91.02 | 6.69 | 2.14 |
| Kahuku | 5.7 | 74.4 | 18.0 | 1.9 | 0.33 | 92.29 | 7.35 | 0.03 |
| Hamakua | ... | 81.9 | 16.1 | 2.0 | .... | 93.45 | 6.21 | 0.34 |
| Pepeekeo | 5.8 | 76.8 | 15.9 | 1.5 | 0.20 | 92.42 | 6.65 | 0.73 |
| Paauhau | 4.4 | 74.3 | 18.1 | 3.2 | 0.24 | 89.24 | 8.74 | 1.78 |
| Koloa | 6.0 | 73.4 | 20.5 | 0.1 | 0.58 | 90.92 | 8.66 | —0.16 |
| Waiakea | 5.6 | 72.1 | 17.8 | 4.5 | 0.48 | 87.78 | 8.77 | 2.97 |
| Hutchinson | 6.2 | 75.9 | 15.9 | 2.0 | 0.19 | 92.25 | 7.11 | 0.45 |
| Honomu | 4.7 | 77.3 | 17.1 | 0.9 | 0.13 | 92.76 | 7.09 | 0.02 |
| Waimanalo | 6.4 | 70.8 | 19.3 | 3.5 | 0.58 | 89.21 | 9.19 | 1.02 |
| Kohala | 4.9 | 75.1 | 17.2 | 2.8 | 0.63 | 89.73 | 8.46 | 1.18 |
| Kilauea | 4.5 | 63.1 | 27.9 | 4.5 | 1.93 | 80.96 | 13.98 | 3.13 |
| Waianae | 3.8 | 74.1 | 17.8 | 4.3 | 0.83 | 88.18 | 7.83 | 3.16 |
| Olowalu | 6.5 | 67.5 | 19.3 | 6.7 | 0.56 | 84.90 | 9.63 | 4.91 |

TABLE NO. 7 SUCROSE DATA

| Factory | Cane Sucrose* | MIXED JUICE | | SYRUP | | SUGAR | | Undetermined Loss per 100 Sucrose* in cane |
|---|---|---|---|---|---|---|---|---|
| | | Sucrose | Gravity Purity | Gravity Purity | Increase in Purity | Sucrose | Sucrose per 100 Sucrose* in cane | |
| H. C. & S. Co. | 15.24 | 12.38 | 90.37† | 90.35 | —0.02 | 97.99 | 92.81 | 0.02 |
| Oahu | 13.70 | 12.20 | 86.77 | 87.31 | 0.54 | 98.45 | 89.89 | 0.31 |
| Ewa | 13.45 | 11.37 | 84.28 | 86.30 | 2.02 | 98.36 | 89.13 | 1.82 |
| Waialua | 14.60 | 12.94 | 87.73 | 88.0 | 0.27 | 98.36 | 86.77 | 2.42 |
| Maui Agr. | 15.37 | 12.88 | 88.40† | 88.47 | 0.07 | 97.67 | 92.26 | —0.04 |
| Pioneer | 14.40 | 13.07 | 85.37 | 86.53 | 1.16 | 98.36 | 89.05 | 1.58 |
| Olaa | 12.48 | 11.46 | 85.08 | 86.8 | 1.72 | 97.94 | 85.84 | 0.53 |
| Lihue | 12.34 | 10.44 | 84.33 | 84.9 | 0.57 | 98.00 | 87.57 | 2.23 |
| H'aw. Sug. | 14.66 | 12.54 | 87.14 | 88.13 | 0.99 | 98.14 | 91.61 | 0.06 |
| Honolulu | 13.95 | 12.11 | 87.63 | 88.6 | 0.97 | 100.0 | 86.63 | 2.51 |
| Onomea | 11.35 | 9.96 | 84.41 | 85.6 | 1.19 | 97.81 | 89.78 | 0.38 |
| Kekaha | 13.77 | 12.44 | 84.80 | 86.12 | 1.32 | 98.14 | 88.93 | 1.04 |
| Hilo | 11.83 | 10.46 | 85.32 | 86.48 | 1.16 | 97.43 | 89.30 | 2.00 |
| Haw. Agr. | 12.07 | 12.07 | 86.28 | 86.82 | 0.54 | 98.21 | 86.72 | 1.48 |
| Wailuku | 13.50 | 10.99 | 85.92 | 87.6 | 1.68 | 98.00 | 88.99 | 0.81 |
| Makee | 11.29 | 10.13 | 81.37 | 81.8 | 0.43 | 97.56 | 82.33 | 2.07 |
| Honokaa | 10.74 | 9.82 | 82.59 | 84.22 | 1.63 | 97.86 | 84.42 | 0.88 |
| Hakalau | 11.74 | 9.86 | 84.56 | 85.66 | 1.10 | 96.95 | 90.95 | 0.65 |
| McBryde | 13.59 | 11.77 | 84.98 | 85.22 | 0.24 | 97.78 | 88.03 | 0.61 |
| Laupahoehoe | 12.33 | 10.47 | 86.60 | 87.24 | 0.64 | 98.25 | 88.37 | 2.07 |
| Kahuku | 11.82 | 10.45 | 82.41 | 84.05 | 1.64 | 98.12 | 90.21 | 0.03 |
| Hamakua | 12.13 | 12.05 | 86.63† | 86.74 | 0.11 | 98.39 | 89.97 | 0.33 |
| Pepeekeo | 12.21 | 11.00 | 84.36 | 86.76 | 2.40 | 98.05 | 90.33 | 0.71 |
| Paauhau | 11.25 | 9.41 | 83.87 | 85.27 | 1.40 | 97.42 | 87.07 | 1.74 |
| Koloa | 11.74 | 10.15 | 82.18 | 84.3 | 2.12 | 98.21 | 88.21 | —0.15 |
| Waiakea | 12.00 | 10.16 | 82.87 | 84.91 | 2.04 | 97.23 | 84.34 | 2.85 |
| Hutchinson | 13.33 | 12.23 | 84.63 | 85.80 | 1.17 | 97.46 | 89.63 | 0.44 |
| Honomu | 11.92 | 9.85 | 83.90 | 86.27 | 2.37 | 98.39 | 91.10 | 0.02 |
| Waimanalo | 12.56 | 10.40 | 80.69 | 82.43 | 1.74 | 97.09 | 87.95 | 1.00 |
| Kohala | 11.92 | 9.69 | 84.26 | 85.99 | 1.73 | 97.62 | 87.21 | 1.15 |
| Kilauea | 9.60 | 9.16 | 78.15 | 78.6 | 0.45 | 97.42 | 77.52 | 2.99 |
| Waianae | 14.18 | 12.61 | 84.46 | 85.18 | 0.72 | 97.61 | 85.57 | 3.06 |
| Olowalu | 13.16 | 10.68 | 81.02 | 82.75 | 1.73 | 96.93 | 83.08 | 4.81 |
| ‡True Average 1929 | 13.08 | 11.44 | 85.58 | 86.60 | 1.02 | 98.00 | 88.75 | 1.05 |
| " " 1928 | 12.69 | 11.22 | 85.15 | 86.23 | 1.08 | 97.86 | 88.49 | 1.21 |
| " " 1927 | 12.46 | 11.01 | 84.53 | 85.86 | 1.33 | 97.79 | 87.96 | 1.13 |
| " " 1926 | 13.35 | 11.68 | 85.38 | 86.66 | 1.28 | 97.67 | 88.41 | 1.20 |

* Pol in bagasse and press cake has been assumed to be the same as sucrose in calculating sucrose in cane.
‡ Clarified juice. † Refinery data from Honolulu not included in average.

According to the above, adding .88 to crop averages for undetermined loss in the large table should give approximately correct figures. With this correction the 1929 figures for undetermined loss become 1.12 per cent.

There has been no increase in the number of factories weighing mixed juice and molasses. Mixed juice is weighed at 35 factories and measured at 4. Molasses is weighed at 28 factories, and measured at 8. Neither weights nor measurements are reported from 3 factories.

pH data are reported from 34 factories. While this is one less than last year, the reduction is due to closing Halawa factory. Three additional factories report clarified juice turbidity, bringing the total so reporting to 27.

Attention is again called to averages in Table 3 for factories that do not use the Petree process and to the necessity of consulting these data when drawing inferences from yearly averages, because of the disturbing effect of data from Petree process factories on many of the averages in the large table.

## Milling

Milling work is appreciably better than in the previous season, although both the average grinding rate and fiber in cane are higher than last year. On the other hand, extraction has been somewhat favored by higher pol. in cane. The average extraction has increased from 97.26 to 97.35, the extraction ratio has decreased from 21.9 to 21.0, and the milling loss has decreased from 2.75 to 2.72. The improvement has brought the extraction to a higher point than in previous seasons except 1920 and 1921, and has reduced the milling loss to a lower point than in any previous season except 1921. Higher extraction is reported from 22 factories, while lower extraction ratio and lower milling loss are each reported from 17 factories. The improvement in milling work, however, may be attributed mainly to results at the larger factories, as 8 of the 10 larger factories report better work.

A condensed tabulation of milling data follows:

| Year | Tons cane per hour | Tonnage ratio | Tonnage fiber ratio | Tons pressure per linear ft. roller | Maceration per cent cane | Milling loss | Extraction ratio | Extraction |
|---|---|---|---|---|---|---|---|---|
| 1921 | 36.58 | 1.40 | 17.9 | .... | 39.30 | 2.64 | 20.1 | 97.43 |
| 1922 | 39.93 | 1.54 | 19.9 | 65.2 | 34.75 | 3.02 | 23.3 | 96.98 |
| 1923 | 42.03 | 1.56 | 20.0 | 66.2 | 35.12 | 2.76 | 21.6 | 97.23 |
| 1924 | 43.63 | 1.62 | 20.6 | 66.9 | 34.90 | 2.78 | 21.0 | 97.33 |
| 1925 | 45.31 | 1.71 | 21.8 | 66.5 | 33.63 | 2.82 | 21.3 | 97.29 |
| 1926 | 46.43 | 1.78 | 22.5 | 67.4 | 33.61 | 2.88 | 21.7 | 97.25 |
| 1927 | 47.87 | 1.78 | 22.2 | 68.2 | 32.53 | 2.73 | 22.2 | 97.23 |
| 1928 | 49.30 | 1.83 | 22.9 | 70.5 | 32.16 | 2.75 | 21.9 | 97.26 |
| 1929 | 50.98 | 1.89 | 23.9 | 70.4 | 33.26 | 2.72 | 21.0 | 97.35 |

This is the eighth consecutive season for which increases in the average grinding rate are recorded. During this period the average figure for tons of cane

ground per hour has increased 40 per cent. Twenty-seven factories report increases this season.

Eighteen factories report increases in pressure against eight reporting decreases. The average for tons pressure per foot of roller has not increased, as moderately large decreases at three or four factories have offset increases reported from a considerable number.

Maceration per cent cane is 1.10 higher than last year, bringing the average to 33.26. This is the first time in seven years that an increase in maceration has been reported. The tendency toward an increase has not been general, the number of factories reporting increases and decreases being practically the same.

The average pol. in bagasse has decreased from 1.55 to 1.54. The improvement is not general, as lower figures are reported but from 16 factories. Moisture in bagasse has decreased from 41.48 to 41.24, the latter figure being lower than in any season except 1920 and 1921. In this case also, but 16 factories report lower figures, so the improvement cannot be considered general.

The purity drop from first expressed to mixed juice in non-Petree process factories has decreased from 2.94 to 2.80. The best previous figure was 2.90, attained in 1923. The purity drop between first expressed and last expressed juice also has decreased, the average being 18.10 this year, against 18.35 in 1928. Reducing these purity drops and at the same time obtaining higher extraction reflects an appreciable improvement, which may be attributed to better mill sanitation, to reduction in the amount of field trash, or to both of these factors. An increase in Java ratio, notwithstanding an increase in cane fiber, tends to corroborate this observation. The Java ratio has increased from 81.5 to 82.0; the highest figure in ten years.

But few additions have been made to milling equipment. A Krajewski crusher has been installed at Olaa and knives have been installed at Kekaha, Onomea, and Waianae, the latter installation being a second set. Increased maceration at a number of the larger factories in combination with the same or heavier pressure appear to be major factors in the improvement in milling work.

Factories are listed in the order of the size of their milling loss in Table 8. Waimanalo, Hakalau and Onomea are again in first, second, and third positions respectively. The first five factories in this table have been at the head of the list for the last three years. Factories that have bettered their position five places or more are: Olowalu, Hawaiian Sugar, H. C. & S. Co., Pioneer, Waimea and Makee. Two of these factories report decreases and four increases in grinding rate. All except Waimea report increases in maceration. The following have dropped five places or more: Hawi, Kilauea, Hamakua, and Waialua. All of these factories report decreases in maceration and increases in grinding rate.

The previous record of 9 factories reporting 98 extraction or over has been equalled this season. Six factories report under 2.0 milling loss, against 5 last year and a previous maximum of 8. No factory has equalled either the previous record of 99.07 for extraction, made at H. C. & S. Co. in 1921, or the previous record of 1.08 for milling loss made at Hakalau in 1925.

## TABLE NO. 8—MILLING RESULTS

Showing the Rank of the Factories on the Basis of Milling Loss.

| Rank | 1928 Rank | Factory | Milling Loss | Extraction Ratio | Extraction | Maceration | Tonnage Ratio | Tonnage Fiber Ratio* |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Waimanalo.... | 1.34 | 10.7 | 98.58 | 40.21 | 2.08 | 27.52 |
| 2 | 2 | Hakalau..... | 1.34 | 11.5 | 98.57 | 38.23 | 1.71 | 21.19 |
| 3 | 3 | Onomea..... | 1.74 | 15.4 | 98.10 | 33.45 | 2.05 | 25.28 |
| 4 | 5 | Honomu..... | 1.76 | 14.9 | 98.20 | 38.97 | 1.47 | 17.82 |
| 5 | 4 | Hilo..... | 1.78 | 15.1 | 98.08 | 33.17 | 1.95 | 24.78 |
| 6 | 10 | Ewa..... | 1.82 | 13.4 | 98.29 | 39.13 | 1.68 | 21.47 |
| 7 | 8 | Paauhau..... | 2.04 | 18.3 | 97.54 | 39.57 | 1.14 | 15.29 |
| 8 | 7 | Wailuku..... | 2.06 | 15.4 | 98.14 | 40.77 | 1.29 | 15.54 |
| 9 | 14 | Olowalu..... | 2.09 | 16.0 | 97.82 | 42.83 | 1.54 | 20.96 |
| 10 | 11 | Lihue..... | 2.20 | 18.1 | 97.79 | 37.05 | 2.29 | 27.94 |
| 11 | 13 | Oahu..... | 2.22 | 16.4 | 98.04 | 30.99 | 1.94 | 23.18 |
| 12 | 9 | Kahuku..... | 2.23 | 19.3 | 97.72 | 30.71 | 1.63 | 19.30 |
| 13 | 12 | Pepeekeo..... | 2.24 | 18.5 | 97.72 | 29.54 | 1.97 | 24.27 |
| 14 | 21 | Haw. Sug..... | 2.27 | 15.6 | 98.00 | 36.59 | 1.71 | 21.89 |
| 15 | 26 | H. C. & S. Co.. | 2.27 | 14.8 | 97.99 | 43.01 | 1.78 | 23.82 |
| 16 | 15 | Kekaha..... | 2.47 | 18.1 | 97.86 | 28.59 | 1.97 | 23.25 |
| 17 | 25 | Pioneer..... | 2.49 | 17.5 | 97.62 | 32.61 | 2.29 | 31.17 |
| 18 | 22 | Maui Agr..... | 2.54 | 16.6 | 97.83 | 39.74 | 1.91 | 24.91 |
| 19 | 6 | Hawi..... | 2.55 | 21.1 | 97.16 | 24.56 | 1.81 | 24.36 |
| 20 | 19 | Kohala..... | 2.67 | 22.6 | 97.15 | 41.53 | 1.59 | 20.07 |
| 21 | 17 | Koloa..... | 2.74 | 23.6 | 96.98 | 33.90 | 1.33 | 17.01 |
| 22 | 18 | Haw. Agr..... | 2.76 | 23.2 | 97.23 | 18.25 | 2.01 | 24.04 |
| 23 | 30 | Waimea..... | 2.81 | 20.7 | 97.38 | 27.33 | 1.56 | 19.75 |
| 24 | 23 | Laupahoehoe... | 2.86 | 23.3 | 97.07 | 35.73 | 1.68 | 21.15 |
| 25 | 24 | Hutchinson.... | 2.92 | 22.0 | 97.15 | 27.48 | 1.92 | 24.83 |
| 26 | 20 | Kilauea..... | 3.32 | 35.0 | 95.70 | 22.78 | 1.74 | 21.37 |
| 27 | 36 | Makee..... | 3.48 | 31.4 | 95.74 | 31.20 | 2.25 | 30.53 |
| 28 | 31 | Waianae..... | 3.49 | 25.0 | 97.00 | 30.31 | 1.58 | 18.93 |
| 29 | 16 | Hamakua..... | 3.61 | 30.2 | 96.24 | 19.54 | 1.42 | 17.69 |
| 30 | 29 | Olaa..... | 3.63 | 29.1 | 96.56 | 27.39 | 2.05 | 24.27 |
| 31 | 32 | Waiakea..... | 3.66 | 30.9 | 96.03 | 37.38 | 1.66 | 21.35 |
| 32 | 28 | McBryde..... | 3.67 | 27.2 | 96.36 | 35.55 | 1.52 | 20.32 |
| 33 | 27 | Waialua..... | 3.73 | 26.1 | 96.66 | 33.23 | 2.59 | 33.10 |
| 34 | 34 | Honolulu..... | 3.76 | 27.4 | 96.91 | 31.97 | 1.89 | 21.34 |
| 35 | 35 | Kaiwiki..... | 4.13 | 33.3 | 95.74 | 26.40 | 1.76 | 22.55 |
| 36 | 37 | Kaeleku..... | 4.21 | 35.2 | 94.98 | 32.28 | 1.83 | 26.08 |
| 37 | 33 | Honokaa..... | 4.26 | 40.0 | 95.02 | 28.21 | 1.68 | 20.90 |
| 38 | 38 | Niulii..... | 4.94 | 48.6 | 93.15 | 26.24 | 1.85 | 26.18 |
| 39 | 40 | Union Mill.... | 6.16 | 54.6 | 92.12 | 20.57 | 1.69 | 24.39 |

* Tonnage ratio multiplied by per cent fiber in cane.

Data from H. C. & S. Co. furnish additional information on the effect of returning mud to the mill; a subject which has been of considerable interest in Hawaii since the introduction of the Petree process. At this factory Peck strainers covered with 100- to 150-mesh screens are used for the mixed juice. The settlings are concentrated in Kopke centrifugal separators, reducing the moisture content to about 76 per cent, and the pol. to between 2.5 and 3.0 per cent. In 1928 the mud from the Kopke separators was returned to the mill. In 1929 the mud was discarded. The reported extraction improved from 97.35 to 97.99, notwithstanding an increase of .68 in cane fiber. These extraction figures, however, are not exactly comparable, as the increase in the amount of bagasse, corresponding to the returned mud, was not taken into consideration in calculating the 1928 extraction. Assuming the same proportion of mud as in 1929, this correction is equivalent to .10 in extraction and the corrected gain in extraction becomes .74. Subtracting the 1929 loss in Kopke mud, .43 leaves a net reduction in losses of .31. Although the grinding rate was 1.34 tons less than in 1928, on account of higher fiber in the cane, the operating capacity as indicated by tonnage-fiber ratio figures, was 3 per cent greater. Moisture in bagasse was decreased from 41.97 to 38.24, and maceration was increased from 35.75 to 43.01, indicating the probability that the improvement in extraction is due both to more effective application of pressure and to ability to apply heavier maceration.

## Boiling House Work

Data for boiling house work indicate an improvement in this department also, although one important detail, clarification, is less satisfactory than last year.

*Clarification:* Referring to data for non-Petree process factories in Table 3, we find that with a decrease of .08 pound in the amount of CaO per ton of cane, the increase in purity from mixed juice to syrup is .04 less than last year. Higher grinding rates in the last few years, with but little increase in facilities for filtering settlings, have rendered it much more difficult to approximate the range of 8.0 to 8.3 pH in the hot limed juice indicated by experimental work as the optimum clarification reaction. Two-thirds of the factories reporting the pH of the hot limed juice, report under 8 pH. There is little question but that the average clarification reaction is below the optimum range and that benefits would accrue if the amount of lime could be increased. Low clarification pH is due principally to the practical necessity of keeping the volume of settlings within the capacity of available filtration equipment. Handling the settlings satisfactorily is the outstanding problem of our present boiling house practice.

Notwithstanding the smaller increase in purity during clarification, the difference between first expressed juice and syrup purity has decreased from 1.58 to 1.46, due to the smaller drop between first expressed and mixed juice purities mentioned in a preceding paragraph. The difference this year is smaller than in recent years except 1923 and 1927, when considerably better increases in purity during clarification were secured.

*Filter Presses:* The loss in press cake per cent pol. in cane (Table 3) has been reduced from .55 to .52. The improvement is due to a reduction of .07 in pol., the weight of press cake remaining the same. The figure in the large table for loss in press cake for all factories is the same as last year. This is because the loss in Kopke mud at H. C. & S. Co., which did not appear as a loss in press cake last year, has offset reductions in filter press loss at other factories.

*Evaporation:* Evaporator capacity has been increased at four factories: Maui Agr., Lihue, Kekaha, and Waiakea. All of these factories report increases in syrup density. The average is 63.65 Brix; an increase of .61 over last year. The calculated amount of water evaporated per hour has increased 4.2 per cent.

*Commercial Sugar:* The pol. of the commercial sugar has increased .13, bringing the average to 97.64, a higher figure than in any previous season. This is the tenth successive season in which increases in sugar pol. have been recorded. The increase in the average is due to increases at factories shipping sugar to Crockett. Higher pol. has been quite general in this group, 19 of the 28 factories reporting increases. The average pol. at factories shipping to the Western refinery has decreased .03, although seven of these factories report increases against 3 reporting decreases. The average pol. for factories shipping to Crockett is 97.75, against an average of 96.88 for factories shipping to the Western refinery.

Data for deterioration factor and low grade sugar purity, are presented in Table 9. Pol. and moisture in commercial sugar are also included, together with marks indicating to which refinery the sugar is shipped. Moisture in commercial sugar has been reduced from .62 to .58. The reduction in moisture has been in slightly greater proportion than the increase in pol., with the result that the deterioration factor has been reduced from .249 to .246. These averages for both moisture and deterioration factor are the lowest on record.

While the average deterioration factor has been decreasing in recent years there is still room for improvement. A deterioration factor of .25 is considered the dividing line between a safe and unsafe moisture content, for experimental work has demonstrated that deterioration is possible above .25. The average deterioration factor, however, is above .25 at 13 of the 36 factories reporting this figure, and just .25 at 7 more of these factories.

*Final Molasses:* The average for final molasses purity has been reduced to 37.02. This is an improvement of .30 over the previous record, made in 1925. Twenty-three factories have reported decreases in molasses purity, against 15 reporting increases. The lowest average for an individual factory, 32.53, is reported from Kahuku. This, however, does not equal the record, 31.81, established by this factory in 1927. The loss of sucrose in molasses per cent pol. in cane has been reduced from 7.71 to 7.40.

TABLE NO. 9

SUGAR DATA

| Factory | Commercial Sugar | | | Low Grade Sugar Purity |
|---|---|---|---|---|
| | Pol | Moisture | Deterioration Factor | |
| H. C. & S. Co. | 97.77 | 0.53 | 0.24 | 73.3 |
| Oahu | 98.23 | 0.42 | 0.24 | 79.13 |
| Ewa | 97.92 | 0.50 | 0.24 | 79.68 |
| Waialua | 97.99 | 0.53 | 0.26 | 74.85 |
| Maui Agr. | 97.52 | 0.62 | 0.25 | 71.74 |
| Pioneer | 98.08 | 0.42 | 0.22 | 76.49 |
| Olaa | 97.55 | 0.60 | 0.24 | 77.0 |
| Lihue | 97.62 | 0.60 | 0.25 | 75.2 |
| Haw. Sug. | 97.95 | 0.54 | 0.26 | 84.38 |
| Honolulu† | .... | ... | ... | 80.1 |
| Onomea | 97.42 | 0.68 | 0.26 | 79.98 |
| Kekaha | 97.65 | 0.59 | 0.25 | 74.71 |
| Hilo* | 96.99 | 0.78 | 0.26 | 78.17 |
| Haw. Agr. | 98.02 | 0.45 | 0.23 | 79.59 |
| Wailuku | 97.46 | 0.60 | 0.24 | 73.0 |
| Makee | 97.19 | 0.74 | 0.26 | 73.35 |
| Honokaa | 97.49 | 0.62 | 0.25 | 66.0 |
| Hakalau* | 96.57 | 0.83 | 0.24 | 73.1 |
| McBryde | 97.61 | 0.62 | 0.26 | 78.7 |
| Laupahoehoe | 97.94 | 0.53 | 0.26 | 77.04 |
| Kahuku | 97.91 | 0.50 | 0.24 | 80.35 |
| Hamakua | 97.75 | 0.50 | 0.22 | 74.34 |
| Pepeekeo | 97.59 | 0.49 | 0.20 | 75.61 |
| Paauhau* | 96.76 | 0.77 | 0.24 | 80.30 |
| Koloa | 98.00 | 0.49 | 0.25 | 75.3 |
| Waiakea | 96.93 | 0.85 | 0.28 | 77.0 |
| Hawi | 97.49 | 0.61 | 0.24 | 75.19 |
| Hutchinson* | 97.12 | 0.60 | 0.21 | 72.37 |
| Honomu | 98.02 | 0.45 | 0.23 | 79.03 |
| Kaiwiki | 96.89 | 0.78 | 0.25 | 86.43 |
| Waimanalo* | 96.51 | 0.70 | 0.20 | 71.74 |
| Kohala | 97.24 | 0.71 | 0.26 | 77.90 |
| Kilauea* | 97.23 | 0.81 | 0.29 | 72.8 |
| Waianae* | 97.08 | 0.76 | 0.26 | 79.82 |
| Kaeleku* | 97.31 | ... | ... | 78.50 |
| Union Mill | 96.85 | 0.99 | 0.31 | 81.50 |
| Niulii* | 96.64 | 1.5 | 0.45 | 78.2 |
| Waimea | 96.81 | ... | ... | 80.3 |
| Olowalu* | 96.37 | 0.90 | 0.25 | 78.03 |
| True Average | 97.64 | 0.58 | 0.246 | 76.56 |

* Sugar shipped to Western Refinery. Other factories except Honolulu ship to Crockett.
† Refined sugar.

Factories are grouped according to molasses purity in the following table:

GRAVITY PURITY FINAL MOLASSES

| 32—33 | 33—34 | 34—35 | 35—36 | 36—37 |
|---|---|---|---|---|
| Kahuku | Hamakua | Honomu | Laupahoehoe | Hilo |
| | Koloa | Pepeekeo | Haw. Sug. | Waianae |
| | | Ewa | Onomea | Makee |
| | | McBryde | Hutchinson | Maui Agr. |
| | | Hakalau | | H. C. & S. |
| | | Pioneer | | Lihue |
| | | | | Waimanalo |

| 37—38 | 38—39 | 39—40 | Over 40 |
|---|---|---|---|
| Kekaha | Kilauea | Oahu | Olaa |
| Honolulu | Hawi | Paauhau | Kaeleku |
| Honokaa | Olowalu | Waiakea | Haw. Agr. |
| Waialua | | Wailuku | Kohala |
| | | | Niulii |
| | | | Kaiwiki |
| | | | Union Mill |

This classification brings out the advantage of crystallization in motion over the older low grade practice. None of the factories where low grade massecuite is boiled blank and crystallized in storage tanks report under 38 purity. Four of the seven factories reporting over 40 purity follow this practice.

Crystallizers have been installed at one factory, Waiakea, and an improvement of 3.20 in final molasses purity has been realized. In the last three years crystallizers have been installed at four other factories, Laupahoehoe, Hamakua, Hutchinson and Waianae, and in each instance material benefits have accrued. At each of these factories, molasses purities averaged 40 or above in seasons immediately preceding the installation of crystallizers. Improvements in molasses purity since these installations are the equivalent of from 1 to 3 per cent in recovery. The superiority, from a practical standpoint, of boiling to grain and crystallization in motion, over blank boiling and crystallization in storage tanks has been demonstrated conclusively by operating data in recent years. There is little question as to the advisability of making the change at factories still following the older practice.

*Undetermined Loss:* The undetermined loss has decreased from .32 to .24, the latter figure being the lowest on record. These figures on a pol. basis, however, are lower than the actual undetermined loss. As pointed out under "Chemical Control," the probable correction is .88, making the 1929 average 1.12 instead of .24 per cent.

## Recovery

The recovery has again increased, the improvement being due in part to higher purity juices and in part to better factory work.

The boiling house recovery has increased from 91.24 to 91.65. This is the highest figure since 1909, at which time higher purities rendered it possible to attain high boiling house recoveries with far less efficient factory work.

The total recovery has increased .47, bringing it to 89.23, the highest figure on record. Higher pol. in commercial sugar corresponds to a decrease of .05 in re-

covery, so, in making a comparison with last year, we may consider that the improvement is .52 rather than .47.

Assuming that the improvement in first expressed juice purity reflects the improvement in the purity of the cane juice as a whole, approximately one-half of the increase in recovery may be attributed to higher purity raw material. The remaining half may be divided approximately as follows: a third to better low grade work, a third to better extraction and lower undetermined losses, and a third to a smaller drop in purity from first expressed to mixed juice.

Comparison of quality ratio data with tons cane per ton of sugar also divide the improvement between better cane and better factory work. It will be noted, however, that this comparison is not on the same basis as the above, figures referring to yield per cent cane instead of yield per cent pol. in cane. Quality ratio figures indicate that an increase of .29 in yield of sugar per cent cane should be secured while .38 was realized. If we correct the former figure for the increase in fiber and the latter for the increase in sugar pol., these figures become .27 indicated increase and .39 obtained.

## Comparison of Actual and Calculated Recoveries

Comparisons in Table 10 are identical with those in the two previous Synopses. Recoveries are compared first with the recovery of a hypothetical factory having no losses other than in final molasses reduced to 37.5 gravity purity, and second, with recovery indicated by "sugar ratio." Factories are listed in the table in the order indicated by the first of these comparisons. The order shown by the second is indicated by figures in next to the last column. No attempt has been made to indicate inaccuracies in control data, which seriously influence the comparative standing determined in this way, though this has been done in previous years. While careful examination will usually give a fair idea of the probable accuracy of control data, it is hardly practicable to decide which data should be designated as inaccurate except on the basis of definite standards. Such standards must be arbitrarily chosen and it is extremely difficult to formulate a set of standards which will be equitable in all cases. It has seemed preferable at this time to present the results of these comparisons at their face value, without attempting to indicate instances where figures for relative standing have been influenced by unreasonably large errors in chemical control. In connection with examining control data for such errors we would note that percentage figures in columns 2 and 3 refer to standards which can be exceeded in practice, and therefore figures of over 100 per cent are not necessarily inconsistent. It is also possible to exceed the "sugar ratio" standards.

Examination of data in Table 10 will disclose considerable differences in the relative standing indicated by these two methods. Some of the larger differences are because purities used in the "sugar ratio" calculations do not coincide closely with actual syrup purities. To a considerable extent, however, these differences in relative standing are due to a deficiency inherent in calculations of this kind. Relative results vary according to the standard chosen for final molasses purity. In one case 37.5, and in the other 33.3 has been used. These comparisons have been

TABLE NO. 10

COMPARISON OF ACTUAL AND THEORETICAL RECOVERIES

| Recovery % Calculated Recovery * | | | | | Recovery % Recovery Indicated by "Sugar Ratio" † | |
|---|---|---|---|---|---|---|
| Rank | Factory | Milling | Boiling House | Over All | Rank | Over All |
| 1 | Kahuku | 97.72 | 105.13 | 103.04 | 1 | 102.78 |
| 2 | Hakalau | 98.57 | 102.00 | 100.78 | 2 | 100.57 |
| 3 | Waimanalo | 98.58 | 101.39 | 100.23 | 11 | 99.38 |
| 4 | Honomu | 98.20 | 101.71 | 100.19 | 7 | 100.02 |
| 5 | Koloa | 96.98 | 102.87 | 100.18 | 10 | 99.41 |
| 6 | Maui Agr. | 97.83 | 101.77 | 99.92 | 3 | 100.30 |
| 7 | Haw. Sug. | 98.00 | 101.61 | 99.78 | 4 | 100.28 |
| 8 | Onomea | 98.10 | 101.05 | 99.46 | 5 | 100.07 |
| 9 | Ewa | 98.29 | 100.84 | 99.40 | 12 | 99.36 |
| 10 | Oahu | 98.04 | 101.05 | 99.36 | 8 | 99.85 |
| 11 | Hamakua | 96.24 | 102.62 | 99.20 | 18 | 98.19 |
| 12 | H. C. & S. Co | 97.99 | 100.91 | 99.14 | 6 | 100.06 |
| 13 | Lihue | 97.79 | 100.89 | 99.05 | 15 | 98.68 |
| 14 | Pepeekeo | 97.72 | 101.16 | 98.92 | 9 | 99.53 |
| 15 | Hutchinson | 97.15 | 101.47 | 98.89 | 14 | 98.85 |
| 16 | Pioneer | 97.62 | 100.87 | 98.78 | 13 | 99.04 |
| 17 | McBryde | 96.36 | 101.92 | 98.56 | 19 | 97.90 |
| 18 | Kekaha | 97.86 | 99.99 | 98.29 | 17 | 98.37 |
| 19 | Hilo | 98.08 | 99.37 | 97.71 | 16 | 98.38 |
| 20 | Wailuku | 98.14 | 99.10 | 97.52 | 22 | 97.11 |
| 21 | Hawi | 97.16 | 99.45 | 97.05 | 26 | 96.32 |
| 22 | Paauhau | 97.54 | 99.14 | 96.89 | 25 | 96.51 |
| 23 | Makee | 95.74 | 100.34 | 96.69 | 31 | 94.55 |
| 24 | Laupahoehoe | 97.07 | 99.21 | 96.57 | 23 | 96.76 |
| 25 | Kohala | 97.15 | 98.97 | 96.42 | 20 | 97.40 |
| 26 | Honolulu | 96.91 | 98.87 | 96.11 | 21 | 97.18 |
| 27 | Waialua | 96.66 | 98.91 | 96.02 | 24 | 96.62 |
| 28 | Haw. Agr. | 97.23 | 98.30 | 95.79 | 27 | 96.14 |
| 29 | Waianae | 97.00 | 98.42 | 95.76 | 28 | 95.44 |
| 30 | Honokaa | 95.02 | 99.68 | 95.18 | 30 | 94.65 |
| 31 | Waiakea | 96.03 | 98.15 | 94.67 | 33 | 93.96 |
| 32 | Kaiwiki | 95.74 | 98.14 | 94.34 | 29 | 94.69 |
| 33 | Olowalu | 97.82 | 96.01 | 94.31 | 34 | 92.94 |
| 34 | Olaa | 96.56 | 96.77 | 93.79 | 32 | 94.37 |
| 35 | Kilauea | 95.70 | 96.84 | 93.45 | 36 | 91.42 |
| 36 | Kaeleku | 94.98 | 96.90 | 92.45 | 35 | 91.89 |
| 37 | Niulii | 93.15 | 98.51 | 92.41 | 38 | 90.63 |
| 38 | Union Mill | 92.12 | 97.79 | 90.56 | 37 | 90.92 |
| 39 | Waimea | 97.39 | 92.28 | 90.12 | 39 | 90.30 |

* Factories are arranged in the order of the ratio of their recovery to that calculated on the basis of 100% extraction, 37.5 gravity purity molasses and no other losses.

† The basis of this calculation is 98.02 extraction, syrup purity one less than the apparent purity of the first expressed juice, gravity purity of molasses 33.33 and no other losses.

continued in the Synopsis pending the development of a better method for comparing factory work, for, notwithstanding the deficiency noted above, which renders such calculations unsuitable for close comparisons, these calculations do give a fair general idea of relative results secured at different factories except in cases where there is evidence of unreasonably large discrepancies in control data.

The summary of losses is given in the usual form in Table 11.

Calculations in this Synopsis have been made by A. Brodie with the assistance of others in this department.

# ANNUAL SYNOPSIS OF MILL DATA—SHOWING RESULTS FROM 39 HAWAIIAN FACTORIES FOR CROP OF 1929

| Factory | Factory No. | Milling Plant (Sizes in Inches) | CANE: Pol | CANE: % Fiber | CANE: Tons per ton metrical sugar | CANE: Tons ground per 24 hours | CANE: Tonnage ratio | BAGASSE: % Moisture | BAGASSE: % Fiber | BAGASSE: Pol per 100 cane | BAGASSE: Pol per 100 pol of cane | BAGASSE: Pol per 100 fiber | BAGASSE: Milling Loss | BAGASSE: Weight per 100 cane | Factory No. | FIRST EXPRESSED JUICE: Brix | FIRST EXPRESSED JUICE: Pol | FIRST EXPRESSED JUICE: Purity | FIRST EXPRESSED JUICE: Pol of cane x 100 | MIXED JUICE: Brix | MIXED JUICE: Pol | MIXED JUICE: Purity | MIXED JUICE: pH Hot Limed Juice | MIXED JUICE: Weight per 100 cane | MIXED JUICE: Pol per 100 cane | MIXED JUICE: Pol per 100 pol of cane | MIXED JUICE: Extraction Ratio | LAST EXPRESSED JUICE: Pol | LAST EXPRESSED JUICE: Purity | MACERATION WATER: Weight per 100 cane | MACERATION WATER: Dilution % normal Juice | Factory No. | CLARIFIED JUICE: Purity | CLARIFIED JUICE: pH | CLARIFIED JUICE: Turbidity | SYRUP: Brix | SYRUP: Purity | SYRUP: Increase in Purity | SYRUP: pH | PRESS CAKE: Pol | PRESS CAKE: Weight per 100 cane | PRESS CAKE: Pol per 100 pol of cane | LIME USED (Pounds available CaO per ton cane): In Juice | In Settlings | Total | COMMERCIAL SUGAR: Pol | COMMERCIAL SUGAR: % Moisture | COMMERCIAL SUGAR: Weight per 100 cane | COMMERCIAL SUGAR: Pol per 100 cane | COMMERCIAL SUGAR: Pol per 100 pol of cane | COMMERCIAL SUGAR: Pol per 100 fiber | COMMERCIAL SUGAR: Total weight tons | Factory No. | FINAL MOLASSES: Weight per ton cane | FINAL MOLASSES: Sucrose per 100 cane | FINAL MOLASSES: Sucrose per ton pol of cane | FINAL MOLASSES: Purity | OTHER KNOWN LOSSES: Sucrose | UNDETERMINED LOSSES: Sucrose | Factory |
|---|---|---

# CANE MILL DATA, SEASON OF 1929

| Factory | Factory No. | MILLING PLANT (Sizes in Inches) | REVOLVING KNIVES: First Set Number | First Set Distance Apart Inches | First Set Distance from Conveyor Inches | First Set Revolutions per Minute | Second Set Number | Second Set Distance Apart Inches | Second Set Distance from Conveyor Inches | Second Set Revolutions per Minute | MILL OPENINGS: Crusher | 1st Mill Front | 1st Mill Back | 2nd Mill Front | 2nd Mill Back | 3rd Mill Front | 3rd Mill Back | 4th Mill Front | 4th Mill Back | 5th Mill Front | 5th Mill Back | Factory No. | SPEED OF ROLLERS—FEET PER MINUTE: Crusher | 1st Mill | 2nd Mill | 3rd Mill | 4th Mill | 5th Mill | 6th Mill | PRESSURE ON ROLLERS—TONS: Crusher | 1st Mill | 2nd Mill | 3rd Mill | 4th Mill | 5th Mill | 6th Mill | Tons Cane per Hour | Tonnage Ratio | Factory No. | Factory |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co. | 6 | K(2),2RC34x78,S72,12RM34x78 | 28 | 9 3/4 | 24 | 1,200 | 56 | 5 | 16 | 1,200 | 1/16 | 3/16 | 1/16 | 3/16 | 0 | 1/8 | 0 | 1/8 | 0 | .... | .... | 6 | 30 | 25 | 24 | 30 | 24 | ... | ... | 190 | 400 | 375 | 460 | 460 | ... | ... | 30.60 | 1.78 | 6 | H. C. & S. Co. |
| " " " | 6 | K(2),2RC34x78,S72,12RM34x78 | 28 | 9 3/4 | 24 | 1,200 | 48 | 5 | 16 | 1,200 | 1/16 | 3/16 | 1/16 | 3/16 | 1/32 | 1/8 | 0 | 1/8 | 0 | .... | .... | 6 | 30 | 25 | 24 | 31 | 24 | ... | ... | 190 | 400 | 375 | 460 | 460 | ... | ... | 30.60 | 1.78 | 6 | " " " |
| Oahu | 20 | K,2RC34x78,S72,12RM34x78 | 28 | 5 1/2 | 18 | 490 | .. | .... | .... | .... | 1/8 | 5/8 | 0 | 11/16 | 0 | 5/8 | 0 | 1/2 | 0 | .... | .... | 20 | 35.5 | 24.4 | 19.4 | 21.7 | 23.3 | ... | ... | 218 | 423 | 438 | 470 | 413 | ... | ... | 48.75 | 1.94 | 20 | Oahu |
| " | 20 | K,2RC34x78,S72,12RM34x78 | 28 | 5 1/2 | 18 | 690 | .. | .... | .... | .... | 1/8 | 9/16 | 0 | 5/8 | 0 | 3/4 | 0 | 1/2 | 0 | .... | .... | 20 | 38.8 | 26.7 | 19.4 | 22.2 | 22.7 | ... | ... | 228 | 454 | 408 | 398 | 226 | ... | ... | 48.75 | 1.94 | 20 | " |
| Ewa | 5 | K(2),2RC33x78,18RM34x78 | 72 | 1 | 15 | 580 | 72 | 1 | 1/2 | 580 | 3/8 | 7/8 | 1/8 | 3/4 | 1/16 | 5/8 | 0 | 3/4 | 1/8 | 5/8 | 1/16† | 5 | 22 | 20 | 22 | 24 | 25 | 29 | 33 | 288 | 453 | 453 | 457 | 366 | 394 | 503 | 83.04 | 1.68 | 5 | Ewa |
| Waialua | 17 | K(2),2RC33x78,12RM34x78 | 76 | 1 1/2 | 16 | 580 | 76 | 1 1/2 | 2 | 580 | 1 | 3/8 | 0 | 3/8 | 0 | 1/2 | 0 | 1/2 | 0 | .... | .... | 17 | 40.3 | 28.1 | 28.1 | 29 | 31.3 | ... | ... | 300 | 490 | 490 | 500 | 560 | ... | ... | 81.28 | 2.59 | 17 | Waialua |
| Maui Agr. | 21 | K(2),3RC34x66,12RM34x66 | 72 | 7/8 | 10 | 450 | 72 | 7/8 | 7/8 | 520 | 7/8x1/4 | 3/8 | 0 | 1/2 | 0 | 3/16 | 0 | 1 16 | 0 | .... | .... | 21 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 48.0 | 1.91 | 21 | Maui Agr. |
| " | 21 | K(2),3RC34x66,12RM34x66 | 72 | 7/8 | 10 | 450 | 72 | 7/8 | 7/8 | 520 | 7/8x1/4 | 3/8 | 0 | 1/2 | 0 | 3/16 | 0 | 1 16 | 0 | .... | .... | 21 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 21 | " |
| Pioneer | 10 | K,2RC34x72,S72,15RM34x72 | 27 | 2 1/4 | 16 | 690 | .. | .... | .... | .... | 1/8 | 7/16 | 3/32 | 7/16 | 1/32 | 7/16 | 1/32 | 7/16 | 1 32 | 7/16 | 0 | 10 | 43 | 26.8 | 27.9 | 28.6 | 28.6 | 32 | ... | 298 | 486 | 440 | 408 | 398 | 129 | ... | 57.47 | 2.29 | 10 | Pioneer |
| Olaa | 36 | K,2RC34x78,S72,12RM9-33x78,3-34x78 | 26 | 2 1/2 | 16 | 600 | .. | .... | .... | .... | 1/4 | 7/8 | 1/8 | 11/16 | 1/8 | 7/16 | 0 | 5/16 | 0 | .... | .... | 36 | 51.5 | 30.5 | 26.5 | 30.7 | 36 | | | 190 | 350 | 280 | 360 | 414 | | | 73.88 | 1.95 | 36 | Olaa |
| Lihue | 27 | K,2RC34x78,S72,12RM34x78 | 18 | 3 3/4 | 14 | 517 | .. | .... | .... | .... | 1/16 | 7/8 | 0 | 7/16 | 0 | 5/16 | 0 | 1/4 | 0 | .... | .... | 27 | 55.6 | 31.7 | 31.7 | 31.3 | 36 | | | 240 | 433 | 432 | 456 | 415 | | | 80.70 | 2.00 | 27 | Lihue |
| Haw. Sug. | 16 | K,2RC27x72,S72,12RM34x78 | 32 | 4 | 15 | 450 | .. | .... | .... | .... | 1/4 | 9/16 | 1/16 | 7/16 | 0 | 3/8 | 0 | 1/4 | 0 | .... | .... | 16 | 30.6 | 21.2 | 24.1 | 20.8 | 22 | | | 264 | 506 | 506 | 504 | 422 | | | 92.65 | 1.71 | 16 | Haw. Sug. |
| Honolulu | 13 | K(2),S54,2RC34x78,9RM34x78 | 24 | 6 | 18 | 565 | 24 | 6 | 4 | 565 | 15/16¶ | 3/4 | 1/8 | 1/2 | 1 16 | 5/8 | 1/16 | .... | .... | .... | .... | 13 | 21.5 | 19.6 | 23.6 | 24 | .... | .... | .... | 227 | 445 | 470 | 446 | .... | .... | .... | 56.58 | 1.89 | 13 | Honolulu |
| Onomea | 34 | K,2RC28x60,S54,12RM32x66 | 22 | 2 1/2 | 18 | 450 | .. | .... | .... | .... | 1/2 | 7/8 | 1/16 | 5/8 | 0 | 1/2 | 0 | 3/8 | 0 | .... | .... | 34 | 23.4 | 21.7 | 21.3 | 21.4 | 21.5 | ... | ... | 96 | 428 | 450 | 456 | 475 | ... | ... | 51.67 | 2.05 | 34 | Onomea |
| Kekaha | 25 | K,2RC24x54,15RM32x60 | 20 | 2 1/4 | 5 1/2 | 710 | .. | .... | .... | .... | 7/8 | 7/8 | 1/4 | 9/16 | 3/16 | 1/2 | 1/8 | 3/8 | 1/16 | 3/8 | 1 32 | 25 | 21 | 16 | 17.7 | 19 | 20 | 26 | ... | ... | 336 | 340 | 375 | 382 | 391 | ... | ... | 49.17 | 1.97 | 25 | Kekaha |
| Hilo | 33 | K,2RC32x66,12RM32x66 | 24 | 2 3/8 | 1 | 400 | .. | .... | .... | .... | 1/8 | 3/4 | 1/16 | 1/4 | 0 | 1/4 | 0 | 1/2 | 0 | .... | .... | 33 | 40.2 | 24.5 | 23.3 | 26.4 | 17.9 | | | 153 | 397 | 397 | 397 | 430 | | | 59.02 | 1.95 | 33 | Hilo |
| Haw. Agr. | 30 | K,3RC32x60,12RM32x66 | 22 | 2 1/2 | 2 | 495 | .. | .... | .... | .... | 5/8‡1x1/2 | 1/4‡ | 1/4 | 11/16 | 1 16 | 1/2 | 1/16 | 3/8 | 0 | .... | .... | 30 | 23.8 | 22.2 | 22.5 | 25.1 | 27.3 | | | 267 | 388 | 403 | 405 | 405 | | | 59.03 | 2.01 | 30 | Haw. Agr. |
| Wailuku | 2 | K,2RC28x72,12RM34x78 | 10 | 6 | 18 | 400 | .. | .... | .... | .... | 1/8 | 3/8 | 0 | 3/8 | 0 | 5/16 | 0 | 1/4 | 0 | .... | .... | 2 | 30.3 | 19.5 | 16.8 | 17.8 | 22.3 | | | 160 | 429 | 460 | 440 | 440 | | | 55.1 | 1.559 | 2 | Wailuku |
| Makee | 14 | K,2RC34x72,S72,9RM34x72 | 22 | 2 1/2 | 6 1/2 | 500 | .. | .... | .... | .... | 0 | 1/2 | 0 | 5/16 | 0 | 1/4 | 0 | .... | .... | .... | .... | 14 | 52.6 | 25.5 | 25.5 | 25.5 | ... | ... | ... | 250 | 437 | 448 | 460 | ... | ... | ... | 54.05 | 2.25 | 14 | Makee |
| Honokaa | 35 | K(2),2RC30x66,12RM32x66 | 16 | 4 | 14 | 400 | 16 | 4 | 4 1/2 | 500 | 5/8 | 5/8 | 1/8 | 3/8 | 3/32 | 5/16 | 1/16 | 1/4 | 0 | .... | .... | 35 | 34.2 | 24.5 | 20.9 | 25.4 | 28 | | | 240 | 400 | 400 | 396 | 400 | | | 59.0 | 1.98 | 35 | Honokaa |
| Hakalau | 7 | 2RC24x54,12RM9-32x60,3-32x66 | .. | ..... | ..... | ... | .. | .... | .... | .... | 0 | 3/4 | 0 | 1/4 | 0 | 1/8 | 0 | 1/4 | 0 | .... | .... | 7 | 30.5 | 21.6 | 24.2 | 26.5 | 15.8 | | | | 322 | 322 | 345 | 330 | | | 46 | 1.74 | 7 | Hakalau |
| McBryde | 12 | K,2RC34x72,S72,9RM34x84 | 76 | 1 1/2 | 6 1/2 | 690 | .. | .... | .... | .... | 3/8 | 1/2 | 0 | 7/16 | 0 | 13/32 | 0 | .... | .... | .... | .... | 12 | 33.5 | 19.5 | 19.5 | 20.5 | .... | | | 250 | 47 | 495 | 502 | .... | | | 67.5 | 1.52 | 12 | McBryde |
| Laupahoehoe | 41 | K,2RC30x60,9RM32x60 | 16 | 3 3/4 | 1 1/2 | 400 | .. | .... | .... | .... | 3/8 | 5/16 | 0 | 3/8 | 0 | 3/16 | 0 | .... | .... | .... | .... | 41 | 30.5 | 21.5 | 17.4 | 19 | .... | | | 250 | 374 | 374 | 374 | .... | | | 55.1 | 1.52 | 2 | Laupahoehoe |
| Kahuku | 43 | K,2RC30x60,S54,9RM34x72 | 10 | 5 1/2 | 25 1/2 | 430 | .. | .... | .... | .... | 7/16 | 5/16 | 1/32 | 3/16 | 0 | 3/16 | 0 | .... | .... | .... | .... | 43 | 31.5 | 16.8 | 19.2 | 22.1 | ... | ... | ... | 135 | 530 | 440 | 480 | ... | ... | ... | 39.05 | 1.63 | 43 | Kahuku |
| Hamakua | 15 | K,2RC30x60,12RM32x60 | 32 | 4 | 2 | 400 | .. | .... | .... | .... | 1/4 | 1/2 | 0 | 3/8 | 0 | 3/8 | 0 | 3/16 | 0 | .... | .... | 15 | 30.5 | 19.7 | 19.7 | 20.1 | 24.2 | ... | ... | ... | 380 | 370 | 370 | 400 | ... | ... | 29.60 | 1.42 | 15 | Hamakua |
| Pepeekeo | 19 | 2RC24x54,9RM32x60 | .. | ..... | ..... | ... | .. | .... | .... | .... | 1/8 | 3/4 | 0 | 3/16 | 0 | 1/8 | 0 | .... | .... | .... | .... | 19 | 31.4 | 21.7 | 23.7 | 26.1 | | | | | 385 | 385 | 385 | | | | 57.20 | 1.95 | 19 | Pepeekeo |
| Paauhau | 24 | 2RC26x60,12RM32x66 | .. | ..... | ..... | ... | .. | .... | .... | .... | 0 | 3/8 | 0 | 3/16 | 0 | 3 16 | 0 | 1 8 | 0 | .... | .... | 24 | 23.9 | 14.7 | 17.8 | 19.7 | 21.8 | | | | 405 | 384 | 420 | .... | | | 56.0 | 1.94 | 24 | Paauhau |
| Koloa | 38 | K,2RC27x60,12RM32x66 | 12 | 4 | 8 | 300 | .. | .... | .... | .... | 1 16 | 3/4 | 3 16 | 1 2 | 1 32 | 7 16 | 0 | 1/4 | 0 | .... | .... | 38 | 24.8 | 17.5 | 19 | 17.6 | 19.5 | | | 297 | 406 | 400 | 384 | 430 | | | 56.0 | 1.94 | 38 | Koloa |
| Waiakea | 3 | K,2RC27x60,9RM32x60 | 36 | 5 3/4 | 4 1/2 | 385 | .. | .... | .... | .... | 0 | 3/8 | 0 | 1/4 | 0 | 5/32 | 0 | .... | .... | .... | .... | 3 | 28 | 19.1 | 21.2 | 24.7 | ... | ... | ... | 135 | 350 | 350 | 360 | ... | ... | ... | 29.38 | 1.76 | 28 | Waiakea |
| Hawi | 26 | K(2),2RC30x54,12RM30x54 | 22 | 4 | 16 | 570 | 28 | 3 | 3 | 570 | 5/8 | 1/8 | 1/16 | 1/4 | 1/32 | 3/16 | 0 | 3/16 | 0 | .... | .... | 26 | 38.2 | 27.3 | 21.9 | 23 | 23 | ... | ... | 155 | 300 | 382 | 350 | 350 | ... | ... | 27.75 | 1.66 | 3 | Waiakea |
| Hutchinson | 31 | K,3RC33x60,9RM32x60 | 22 | 2 1/2 | 1 1/2 | 500 | .. | .... | .... | .... | 5/8x1/16 | 1/2 | 0 | 3/16 | 0 | 1/8 | 0 | .... | .... | .... | .... | 31 | 19 | 17.2 | 19.9 | 22 | | | | 400 | 362 | 362 | 360 | | | | 30.61 | 1.81 | 26 | Hawi |
| Honomu | 37 | 3RC33x60,9RM32x60 | .. | ..... | ..... | ... | .. | .... | .... | .... | 3/4x1/16 | 5/8 | 0 | 9/32 | 0 | 1/4 | 0 | .... | .... | .... | .... | 37 | 20.4 | 17.6 | 20.2 | 22.4 | | | | 356 | 324 | 324 | | | | | 44.1 | 1.96 | 37 | Hutchinson |
| Kaiwiki | 32 | K,2RC24x60,9RM32x60 | 18 | 3 | 3 | 350 | .. | .... | .... | .... | 3/4 | 9/16 | 0 | 1 4 | 0 | 1/4 | 0 | .... | .... | .... | .... | 32 | 22.5 | 18.2 | 21 | 23 | .... | .... | .... | .... | 340 | 347 | 341 | .... | .... | .... | 29.38 | 1.76 | 32 | Kaiwiki |
| Waimanalo | 1 | K,3RC31x54,9RM30x54 | 28 | 1 7/8 | 3 1/2 | 495 | .. | .... | .... | .... | 1/2x1/16 | 3/8 | 0 | 1/4 | 0 | 1/8 | 0 | .... | .... | .... | .... | 1 | 21.5 | 20.7 | 19.5 | 19.5 | ... | ... | ... | 358 | 358 | 358 | 358 | ... | ... | ... | 28.88 | 1.68 | 1 | Waimanalo |
| Kohala | 40 | K(2),3RC30x60,9RM32x60 | 12 | 4 | 18 | 375 | 36 | 1 1/2 | 1 1/2 | 400 | 5/8x5/16 | 3/8 | 0 | 1 4 | 0 | 3 16 | 0 | .... | .... | .... | .... | 40 | 22 | 19 | 25 | 28 | | | | | 350 | 340 | 360 | .... | | | 26.56 | 1.59 | 40 | Kohala |
| Kilauea | 23 | K,3RC32x60,9RM32x60 | 22 | 2 1/2 | 3 | 450 | .. | .... | .... | .... | 7/16x1/4 | 1/4 | 0 | 3/16 | 0 | 1/8 | 0 | .... | .... | .... | .... | 23 | 18 | 19.5 | 26.5 | 30.6 | | | | | | | | | | | | | | |
| Waianae | 9 | K(2),12RM9-30x60,3-32x60 | 36 | 2 1/2 | 10 | 400 | 36 | 2 1/2 | 4 | 400 | .... | 3/4 | 1/16 | 3/8 | 0 | 1/2 | 0 | 3/8 | 0 | .... | .... | 9 | .... | 16.9 | 16.9 | 16.9 | 17.6 | .... | .... | .... | 310 | 320 | 310 | 312 | .... | .... | | 25.0 | 1.75 | 25 | Kilauea |
| Kaeleku | 47 | K,2RC24x54,9RM32x60 | 9 | 6 | 8 | 250 | .. | .... | .... | .... | 1/4 | 3/4 | 1/16 | 5/16 | 0 | 3/16 | 0 | .... | .... | .... | .... | 47 | 19.8 | 16.6 | 18 | 20.4 | .... | .... | .... | .... | 274 | 244 | 274 | 314 | .... | .... | 26.30 | 1.58 | 9 | Waianae |
| Union Mill | 11 | K,9RM30x60 | 15 | 3 3/4 | 8 | 440 | .. | .... | .... | .... | .... | 5/8 | 0 | 1/4 | 0 | 3/16 | 0 | .... | .... | .... | .... | 11 | ... | 18.5 | 18.9 | 21.2 | .... | .... | .... | .... | 347 | 330 | 355 | .... | .... | .... | 30.54 | 1.83 | 47 | Kaeleku |
| Niulii | 39 | K,9RM30x54 | 9 | 6 | 3 1/2 | 580 | .. | .... | .... | .... | .... | 3/8 | 1/16 | 3/16 | 0 | 1/8 | 0 | .... | .... | .... | .... | 39 | ... | 20.2 | 22 | 22 | .... | .... | .... | .... | 313 | 273 | 308 | .... | .... | .... | 21.08 | 1.69 | 11 | Union Mill |
| Waimea | 4 | 2RC24x48,12RM26x42 | .. | ..... | ..... | ... | .. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 212 | 218 | 222 | .... | .... | .... | 18.72 | 1.85 | 39 | Niulii |
| Olowalu | 18 | K,3RC28x48,9RM27x48 | 16 | 3 | 3 | 540 | .. | .... | .... | .... | 0 | 1/2 | 1/8 | 3/8 | 0 | 1/4 | 0 | 3/16 | 0 | .... | .... | 4 | 20.4 | 13.6 | 14.1 | 13.6 | 17.0 | .... | .... | .... | 215 | 200 | 174 | 174 | .... | .... | 15.96 | 1.56 | 4 | Waimea |
| | | | | | | | | | | | 3/8x0 | 3/8 | 0 | 1/4 | 0 | 3/16 | 0 | .... | .... | .... | .... | 18 | 22.6 | 22.6 | 20 | 20 | | | | 230 | 230 | 260 | 260 | | | 16.44 | 1.54 | 18 | Olowalu |

* Tons Cane for one tandem.
† 6th Mill openings ½x0, returner bar from top roller, 1⅝, 1½, 1⅝.
‡ Point to point.
¶ Mesh.

# FACTORY EQUIPMENT INCLUDING IMPROVEMENTS INSTALLED FOR THE 1930 CROP

**Dimensions are given for Mill Equipment and Stacks.** Other data refer to per ton cane hour rated capacity.

| Factory | Factory No. | Capacity T. C. H. Rated capacity | Capacity at 2.0 tonnage ratio | MILLING PLANT (Sizes in Inches) Diameter x Stroke (No. of rollers in parentheses) | MILL ENGINES | BOILERS Sq. Ft. b Water tube | BOILERS Sq. Ft. b Fire tube | FURNACES Grate area sq. ft. | FURNACES Combustion volume cu. ft. | STACKS Dia. at top, ft. | STACKS Height, ft. | STACKS Dia. at top, ft. | STACKS Height, ft. | GENERATORS K. V. A. | Factory No. | JUICE HEATERS Sq. Ft. Mixed juice baffled | JUICE HEATERS Sq. Ft. Mixed juice unbaffled | JUICE HEATERS Sq. Ft. Clarified juice | SETTLING TANKS Cu. Ft. Intermittent | SETTLING TANKS Cu. Ft. Continuous | FILTERS Sq. Ft. Plate and frame | FILTERS Sq. Ft. Continuous, Oliver | EVAPORATORS Sq. Ft. Pre-evaporator | EVAPORATORS Sq. Ft. Triple | EVAPORATORS Sq. Ft. Quadruple | PAN SUPPLY TANKS Cu. Ft. Syrup and Remelt | PAN SUPPLY TANKS Cu. Ft. Molasses | VACUUM PANS Commercial Sugar Sq. ft. | VACUUM PANS Commercial Sugar Cu. ft. | VACUUM PANS Low Grade Sq. ft. | VACUUM PANS Low Grade Cu. ft. | VACUUM PANS Total Sq. ft. | VACUUM PANS Total Cu. ft. | VACUUM PUMPS Cu. ft. per minute | CRYSTALLIZERS Cu. Ft. Without cooling coils | CRYSTALLIZERS Cu. Ft. With cooling coils | CRYSTALLIZERS Cu. Ft. Tanks | CENTRIFUGALS Screen Area Sq. Ft. Commercial sugar | CENTRIFUGALS Screen Area Sq. Ft. Low grade | CENTRIFUGALS Screen Area Sq. Ft. Total | Factory No. | Factory |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. C. & S. Co.* | 6 | 140 | 140.8 | K(4),2RC78(2),S72(2),12RM78(2) | 16x36(2),28x60(9),22x48(3) | 56.9 | 326.6 | 3.1 | 118.3 | 12 | 180 | ... | ... | 13.4 | 6 | 11.0 | 37.0 | ... | .... | 109.1P | 1.55K | ... | 37.8 | .... | 264.8 | 48.3 | 30.6 | 41.0 | 40.0 | 30.3 | 37.1 | 71.3 | 77.1 | 41.0 | 245.7 | .... | .... | 1.65 | 5.98 | 7.63 | 6 | H. C. & S. Co |
| Oahu* | 20 | 145 | 140.8 | K(2),2RC78(2),S72(2),12RM78(2) | 24x48(5),30x60(9) | 323.0 | .... | 2.4 | 35.9 | 10 | 231 | 10 | 173 | 15.5 | 20 | 6.2 | 22.1 | ... | 38.0 | 63.0d | ..... | 8.3 | 200.0 | 23.7 | 39.4 | 46.9 | 18.0 | 29.4 | 31.8 | 21.4 | 20.9 | 50.8 | 52.7 | 25.5 | 75.8 | 170.5 | .... | 1.76 | 5.28 | 7.04 | 5 | Ewa |
| Waialua | 17 | 100 | 70.4 | K(2),2RC78,12RM78 | 30x60(11),30x54(9) | 347.7 | .... | 7.6 | .... | 7 | 137 | 8 | 150 | 36.2 | 5 | 23.6 | .... | ... | 106.8 | .... | 82.1 | ... | 63.2 | .... | 310.5 | 46.9 | 18.0 | 29.4 | 31.8 | 21.4 | 20.9 | 50.8 | 52.7 | 25.5 | 75.8 | 170.5 | .... | 1.76 | 5.28 | 7.04 | 17 | Waialua |
| Maui Agr.* | 21 | 110 | 100.8 | K(4),3RC66(2),12RM66(2) | 28x42(6),28x48(9) | 352.8 | .... | .. | .... | 8 | 150 | ... | ... | 25.0 | 21 | 36.6 | .... | 13.2 | .... | 94.6P | ..... | ... | 100.0 m | .... | 230.0 | 53.2 | 27.8 | 67.8 | 33.4 | 38.8 | 30.9 | 106.6 | 64.3 | .... | 296.0 | .... | .... | 1.14 | 2.83 | 3.97 | 21 | Maui Agr. |
| Pioneer | 10 | 90 | 72.0 | K,2RC72,S72,15RM72 | 16x36(2),26x42(6),28x54(9) | 216.4 | 163.6 | 5.2 | 119.7 | 12 | 230 | ... | ... | 11.1 | 10 | 24.9 | 20.0 | ... | 78.8 | .... | 71.1 | ... | .... | .... | 266.7 | 55.7 | 32.4 | 45.4 | 43.3 | 33.7 | 28.8 | 79.1 | 72.1 | 66.3 | 205.5 | .... | 233.3 | 1.86 | 6.89 | 8.75 | 10 | Pioneer |
| Olsa | 36 | 80 | 70.4 | K,2RC78,S72,12RM78 | 18x42(2),26x48(3),28x60(9) | 96.0 | 254.0 | 3.0 | 58.0 | 9.3 | 180 | ... | ... | 15.6 | 36 | .... | 31.4 | ... | 70.0 | .... | 35.0 | 7.5 | .... | .... | 266.7 | 30.0 | 70.8 | 35.0 | 38.8 | 32.5 | 32.5 | 67.5 | 71.3 | 45.0 | 212.5 | .... | .... | 2.09 | 2.62 | 4.71 | 36 | Olsa |
| Lihue | 27 | 90 | 70.4 | K,2RC78,S72,12RM78 | 18x42(2),28x54(6),28x48(6) | 212.4 | 195.8 | 3.2 | 68.4 | 12 | 194 | ... | ... | 10.4 | 27 | 28.8 | 15.5 | ... | .... | 58.8 | 85.7 | ... | .... | .... | 301.0e | 20.5 | 23.3 | 62.1 | 40.0 | 22.4 | 25.0 | 84.5 | 65.0 | 15.6 | 170.0 | 9.4 | .... | 1.40 | 4.20 | 5.60 | 27 | Lihue |
| Haw. Sug | 16 | 60 | 70.4 | K,2RC72,S72,12RM78 | 20x42(2),28x54(6),28x54(6) | 246.8 | 174.6 | 5.6 | 42.2 | 8 | 184 | ... | ... | ... | 16 | 23.3 | 35.0 | ... | .... | 66.7d | 88.2 | ... | .... | .... | 220.1 | 32.4 | 49.6 | 38.9 | 43.8 | 25.3 | 25.0 | 64.2 | 68.8 | .... | 193.3 | .... | 120.0 | 2.09 | 3.67 | 5.76 | 16 | Haw. Sug. |
| Honolulu | 13 | 60 | 70.4 | K(2),2RC78,12RM78 | 28x48(5),28x60(9) | 636.0 | .... | 6.4† | 121.9† | 9 | 180 | ... | ... | 25.0 | 13 | 23.3 | .... | 11.7 | .... | 50.0d | 80.3 | ... | 149.3 | .... | 184.9 | 33.6 | 57.6 | 75.9 | 40.0 | 44.4 | 30.0 | 120.3 | 70.0 | 46.4 | 280.0 | .... | .... | 3.62 | 4.80 | 8.42 | 13 | Honolulu |
| Onomea | 34 | 50 | 50.4 | K,2RC60,S54,12RM66 | 22x42(5),26x54(9) | 254.7 | 98.5 | 3.8 | 37.0 | 6.5 | 190 | ... | ... | 1.8 | 34 | 28.4 | 25.5 | ... | 75.7 | .... | 88.0 | ... | 70.0 | .... | 257.6 | 25.2 | 32.4 | 35.0 | 34.8 | 14.8 | 17.7 | 49.8 | 52.5 | 19.2 | .... | 154.2 | 220.0 | 2.51 | 4.19 | 6.70 | 34 | Onomea |
| Kekaha | 25 | 50 | 50.0 | K,2RC54,15RM60 | 16x32(2),28x54(9),24x54(6) | 122.8 | 254.0 | 2.5 | 48.0 | 6 | 125 | ... | ... | .... | 25 | 14.0 | 12.0 | ... | .... | 64.0d | 79.0 | ... | 116.7 | .... | 250.0 | 24.0 | 26.6 | 53.4 | 45.3 | 7.7 | 15.0 | 61.1 | 60.3 | 33.5 | 240.0 | 32.0 | .... | 1.68 | 5.92 | 7.60 | 25 | Kekaha |
| Hilo | 33 | 50 | 50.4 | K,2RC66,12RM66 | 26x54(11),22x42(3) | 394.9 | .... | 3.4 | 50.7 | 7 | 143 | ... | ... | 18.7 | 33 | 23.7 | 14.2 | ... | 79.6 | .... | 120.8 | ... | 79.3 | 208.4 | .... | 44.3 | 44.3 | 38.6 | 36.0 | 25.0 | 20.0 | 63.6 | 56.0 | 19.2 | 136.8 | 11.4 | 179.3 | 2.51 | 5.02 | 7.53 | 33 | Hilo |
| Haw. Agr. | 30 | 50 | 50.4 | K,3RC60,12RM66 | 24x48(6),26x54(9) | 480.8 | .... | 5.2 | 41.5 | 6.7 | 120 | 7.5 | 110 | 12.5 | 30 | 23.7 | .... | 13.5 | 113.0 | .... | 122.0 | ... | 100.0 | .... | 225.6 | 42.5 | 50.0 | 34.6 | 36.7 | 24.7 | 24.0 | 59.3 | 60.7 | 106.7 | 52.7 | .... | 540.0 | 3.35 | 5.03 | 8.38 | 30 | Haw. Agr. |
| Wailuku | 2 | 50 | 70.4 | K,2RC72,12RM78 | 23x54(5),28x60(9) | 241.3 | 152.4 | 3.9 | 56.6 | 8 | 169 | ... | ... | 10.0 | 2 | 25.3 | .... | ... | 88.5 | .... | 81.6 | ... | 80.5 | .... | 230.0 | 43.2 | 42.8 | 35.2 | 34.7 | 28.0 | 28.0 | 63.2 | 62.7 | 25.6 | 260.6 | .... | .... | 1.68 | 6.30 | 7.98 | 2 | Wailuku |
| Makee | 14 | 60 | 48.0 | K,2RC72,S72,9RM72 | 16x36(2),28x60(9) | 204.7 | 196.3 | .. | .... | 9.3 | 164 | ... | ... | 4.2 | 14 | .... | 30.0 | ... | .... | 57.7 | 70.6 | ... | .... | .... | 203.3 | 30.8 | 22.1 | 38.3 | 50.0 | 52.5 | 41.7 | 90.8 | 91.7 | 36.5 | 200.0 | .... | .... | 2.09 | 3.14 | 5.23 | 14 | Makee |
| Honokaa | 35 | 45 | 50.4 | K(2),2RC66,12RM66 | 22x42(5),26x54(9) | 144.9 | 338.7 | 3.7 | 38.4 | 7.3 | 179 | ... | ... | .... | 35 | 28.0 | .... | ... | 69.0 | .... | 106.7 | ... | 86.0 | .... | 258.7 | 27.5 | 52.0 | 61.6 | 54.9 | 19.5 | 22.4 | 81.2 | 77.3 | 47.3 | 200.0 | .... | 222.2 | 2.79 | 5.24 | 8.03 | 35 | Honokaa |
| Hakalau | 7 | 35 | 41.7 | 2RC54,12RM9-60,3-66 | 26x54(11),18x42(3) | 344.7 | 145.1 | 5.8 | 46.9 | 5 | 243 | ... | ... | 2.1 | 7 | 19.4 | 15.9 | ... | 109.1 | .... | 120.0 | ... | 85.8 | .... | 291.7 | 47.4 | 36.7 | 31.3 | 37.0 | 17.2 | 21.3 | 48.5 | 58.3 | 60.2 | 277.5 | .... | 158.9 | 2.39 | 5.98 | 8.37 | 7 | Hakalau |
| McBryde | 12 | 50 | 65.3 | K,2RC72,S72,9RM84 | 24x48(5),28x48(6) | 364.4 | .... | 2.1h | 158.9 | 10.5 | 225 | ... | ... | 25.0 | 12 | 22.4 | .... | ... | .... | 60.2d | 132.2 | ... | 69.2 | .... | 212.8 | 64.8 | 65.9 | 38.5 | 37.9 | 34.3 | 36.0 | 72.8 | 73.9 | 106.7 | 248.0 | .... | .... | 2.51 | 4.19 | 6.70 | 12 | McBryde |
| Laupahoehoe | 41 | 30 | 33.3 | K,2RC60,9RM60 | 24x48(5),24x56(6) | 329.1 | 254.0 | 5.5 | 45.1 | 6.5 | 150 | ... | ... | 2.7 | 41 | 23.3 | .... | ... | 74.7 | .... | 116.7 | ... | .... | .... | 330.4 | 56.0 | 63.0 | 74.1 | 73.3 | 28.8 | 36.7 | 102.9 | 110.0 | 90.1 | 233.0 | .... | .... | 2.79 | 8.28 | 11.07 | 41 | Laupahoehoe |
| Kahuku | 43 | 40 | 48.0 | K,2RC60,S54,9RM72 | 14x36(2),28x48(9) | 269.8 | 190.5 | 3.7 | 58.4 | 8 | 152 | ... | ... | 15.0 | 43 | .... | 30.2 | ... | 83.2 | .... | 134.9 | ... | .... | .... | 340.9 | 50.1 | 43.2 | 46.8 | 49.0 | 27.0 | 22.1 | 73.8 | 71.1 | 30.2 | 180.3 | .... | .... | 2.09 | 4.58 | 6.67 | 43 | Kahuku |
| Hamakua | 15 | 30 | 41.7 | K,2RC60,12RM60 | .... | 423.3 | 4.3 | 44.7 | 7 | 140 | ... | ... | 7.5 | 15 | 17.6 | 25.3 | ... | .... | 121.8P | ..... | ... | .... | .... | 329.0 | 41.0 | 49.5 | 44.6 | 45.0 | 11.0 | 14.2 | 55.6 | 59.2 | 30.8 | .... | 133.3 | 480.3 | 2.79 | 5.67 | 8.46 | 15 | Hamakua |
| Pepeekeo | 19 | 30 | 33.3 | 2RC54,9RM60 | 26x54(11) | 146.2 | 254.0 | 8.8 | 55.3 | 7.5 | 130 | ... | ... | .... | 19 | 30.9 | .... | 23.2 | .... | 51.3 | 117.3 | ... | 83.0 | 207.0 | .... | 38.2 | 31.2 | 38.7 | 39.0 | 26.1 | 28.5 | 64.8 | 67.5 | 25.6 | 70.0 | 111.3 | .... | 2.79 | 5.58 | 8.37 | 19 | Pepeekeo |
| Paauhau | 24 | 35 | 50.4 | 2RC60,12RM66 | 20x48(5),26x54(9) | 103.1 | 235.9 | 4.8 | 52.8 | 5.8 | 110 | ... | ... | ... | 24 | .... | 28.3 | ... | 83.4 | .... | 121.1 | ... | .... | .... | 241.2 | 33.2 | 18.0 | 37.9 | 38.5 | 14.6 | 11.7 | 52.5 | 50.2 | 18.9 | .... | .... | 741.1 | 2.39 | 3.59 | 5.98 | 24 | Paauhau |
| Koloa | 38 | 36 | 50.4 | K,2RC60,12RM66 | 24x48(8),24x48(6) | .... | 346.4 | 4.6 | 46.7 | 7.5 | 140 | ... | ... | 2.8 | 38 | 35.1 | 14.5 | ... | 60.0 | .... | 115.6 | ... | .... | .... | 258.5 | 32.8 | 59.7 | 32.2 | 30.6 | 25.0 | 27.8 | 57.2 | 58.4 | 25.0 | 177.8 | .... | 200.0 | 3.49 | 4.07 | 7.56 | 38 | Koloa |
| Waiakea | 3 | 30 | 33.3 | K,2RC60,9RM60 | 26x54(11) | .... | 450.3 | 5.7 | 36.3 | 7 | 115 | ... | ... | 16.7 | 3 | 23.7 | .... | ... | 82.0 | .... | 123.6 | ... | .... | .... | 330.7 | 42.0 | 34.8 | 55.8 | 45.0 | 28.6 | 24.0 | 84.4 | 69.0 | 72.9 | 280.0 | .... | .... | 2.79 | 4.19 | 6.98 | 3 | Waiakea |
| Hawi | 26 | 33 | 33.8 | K(2),2RC54,12RM54 | 18x42(5),22x54(9) | 218.2 | 208.1 | 5.8 | 133.3 | 6 | 105 | 6 | 105 | 34.8 | 26 | 47.1 | .... | ... | 92.0 | .... | 150.0 | ... | 148.7 | 271.2 | .... | 37.8 | 64.3 | 51.1 | 44.6 | 21.3 | 17.9 | 72.4 | 62.5 | 49.0 | 236.4 | .... | 170.3 | 2.54 | 6.27 | 8.81 | 26 | Hawi |
| Hutchinson | 31 | 30 | 33.3 | K,3RC60,9RM60 | 22x42(3),26x40(9) | 329.0 | 169.3 | 6.3 | .... | 6 | 110 | ... | ... | 16.7 | 31 | .... | 42.0 | ... | 73.8 | .... | 141.2 | ... | 69.0 | .... | 243.1 | 39.9 | 93.2 | 25.5 | 40.0 | 31.2 | 26.7 | 56.7 | 66.7 | 29.9 | 266.7 | .... | .... | 2.79 | 4.89 | 7.68 | 31 | Hutchinson |
| Honomu | 37 | 25 | 33.3 | 3RC60,9RM60 | 22x42(3),24x48(9) | 88.9 | 228.6 | 2.3 | 41.3 | 7 | 140 | ... | ... | ... | 37 | 21.8 | 19.4 | 11.0 | 72.9 | .... | 160.0 | ... | 72.0 | .... | 215.2 | 67.9 | 54.3 | 39.0 | 41.4 | 15.1 | 13.1 | 54.1 | 54.5 | 39.5 | 200.0 | .... | .... | 3.35 | 5.13 | 8.48 | 37 | Honomu |
| Kaiwiki | 32 | 30 | 33.3 | K,2RC60,9RM60 | 16x36(2),24x54(9) | .... | 338.7 | 4.5 | 46.4 | 6 | 100 | ... | ... | ... | 32 | 17.9 | .... | ... | 56.0 | .... | 88.5 | ... | .... | .... | 202.5e | 17.6 | 62.2 | 30.0 | 19.7 | 7.7 | 8.7 | 37.7 | 28.4 | 55.2 | .... | .... | 623.3 | 1.83 | 1.83 | 3.66 | 32 | Kaiwiki |
| Waimanalo | 1 | 25 | 27.0 | K,3RC54,9RM54 | 20x42(6),20x42(6) | 313.5 | 304.8 | 6.6‡ | .... | 6.5 | 140 | ... | ... | 15.0 | 1 | .... | 38.9 | ... | 79.5 | .... | 135.7 | ... | .... | .... | 320.0 | 30.0 | 50.0 | 48.0 | 48.0 | 24.0 | 24.0 | 72.0 | 72.0 | 58.0 | 336.0 | .... | .... | 3.35 | 5.03 | 8.38 | 1 | Waimanalo |
| Kohala | 40 | 30 | 33.3 | K(2),3RC60,9RM60 | 22x48(6),26x48(6) | 488.6 | .... | 5.6 | 45.3 | 6 | 138 | ... | ... | 3.1 | 40 | .... | 26.7 | ... | 70.6 | .... | 136.8 | ... | .... | 248.4 | .... | 41.9 | 50.4 | 38.9 | 32.7 | 20.7 | 23.5 | 59.6 | 56.2 | 34.5 | 100.0 | 100.0 | .... | 3.14 | 1.83 | 4.97 | 40 | Kohala |
| Kilauea | 23 | 30 | 33.3 | K,3RC60,9RM60 | 18x42(3),24x54(9) | 201.1 | 169.3 | 5.9 | 78.7 | 6.5 | 115 | ... | ... | .... | 23 | .... | 18.2 | ... | 83.2 | .... | 142.3 | ... | 40.0 | 130.0 | .... | 44.2 | 18.3 | 57.0 | 64.1 | 11.0 | 8.2 | 68.0 | 72.3 | 33.0 | 114.0 | .... | 1105.3 | 2.79 | 3.36 | 6.15 | 23 | Kilauea |
| Waianae | 9 | 30 | 33.3 | K,2RC54,9RM60 | 24x42(9),20x42(3) | .... | 338.7 | 4.4 | 43.3 | 7 | 126 | ... | ... | ... | 9 | 13.3 | .... | 13.3 | 92.0 | .... | 94.5 | ... | .... | .... | 233.9 | 20.0 | 30.0 | 29.2 | 26.8 | 24.0 | 25.2 | 53.2 | 52.0 | 27.4 | 110.0 | .... | 287.3 | 2.09 | 2.09 | 4.18 | 9 | Waianae |
| Kaeleku | 47 | 30 | 33.3 | K,2RC54,9RM60 | 14x36(2),26x54(9) | .... | 338.7 | 4.0 | 38.4 | 5 | 105 | ... | ... | .3 | 47 | ... | 39.9 | ... | 76.5 | .... | 79.6 | ... | 28.1 | 117.8 | .... | 44.2 | 25.1 | 31.7 | 26.7 | 6.0 | 6.7 | 37.7 | 33.4 | 29.2 | .... | .... | 713.3 | 2.44 | 1.83 | 4.27 | 47 | Kaeleku |
| Union Mill | 11 | 20 | 25.0 | K,9RM60 | 18x42(3),24x48(6) | .... | 401.3 | 4.5 | 43.9 | 5 | 135 | ... | ... | ... | 11 | 35.1 | .... | ... | 86.3 | .... | 175.0 | ... | .... | .... | 247.2e | 45.0 | 40.5 | 30.9 | 29.7 | 7.5 | 7.5 | 38.4 | 37.2 | 43.0 | 88.7 | .... | 358.1 | 1.83 | 3.66 | 5.49 | 11 | Union Mill |
| Niulii | 39 | 18 | 20.3 | K,9RM54 | 18x42(6),18x42(3) | .... | 282.2 | 5.2 | 30.4 | 4.5 | 114 | ... | ... | ... | 39 | ... | 33.6 | ... | 70.5 | .... | 89.2 | ... | .... | 158.4 | .... | 64.0 | 85.3 | 13.9 | 22.2 | 9.4 | 11.1 | 23.3 | 33.3 | 19.7 | .... | .... | 611.1 | 2.04 | 4.07 | 6.11 | 39 | Niulii |
| Waimea | 4 | 15 | 20.4 | 2RC48,12RM42 | 18x42(8),16x42(6) | .... | 338.7 | 4.9 | 48.0 | 4.5 | 110 | ... | ... | ... | 4 | ... | 36.0 | ... | 85.5 | .... | 120.0 | ... | .... | .... | 255.0 | 32.0 | 34.0 | 50.0 | 42.0 | 6.0 | 4.7 | 56.0 | 46.7 | 24.0 | 186.7 | .... | 288.3 | 2.40 | 4.10 | 6.50 | 4 | Waimea |
| Olowalu | 18 | 20 | 21.3 | K,3RC48,9RM48 | 22½x48(6),18x42(6) | .... | 373.3 | 5.6 | 24.3 | 4.3 | 108.5 | ... | ... | ... | 18 | ... | 19.6 | ... | 90.5 | .... | 83.4 | ... | 78.4 | 152.3 | .... | 28.4 | 18.9 | 44.0 | 39.2 | 7.5 | 7.6 | 51.5 | 46.8 | 16.1 | .... | .... | 672.2 | 2.75 | 1.83 | 4.58 | 18 | Olowalu |

* Two tandems.
† Does not include 3 oil fired boilers.
‡ Does not include 1 oil fired boiler.
h Hearth area.
b Boiler data from Bureau of Boiler Inspection.

P Divided clarification.
d Dorr.
K Kopke centrifugal separators.
m Dead end double effect.
e Vapor from oversize first cell used for heating.

# FACTORY EQUIPMENT INCLUDING IMPROVEMENTS INSTALLED FOR THE 1930 CROP

TABLE NO. 11

SUMMARY OF LOSSES

| FACTORY | POUNDS POL PER TON OF CANE | | | | | | POL PER 100 CANE | | | | | | POL PER 100 POL OF CANE | | | | | | Syrup Purity | FACTORY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bagasse | Press Cake | Molasses | Other Known | Undetermined | TOTAL | Bagasse | Press Cake | Molasses | Other Known | Undetermined | TOTAL | Bagasse | Press Cake | Molasses | Other Known | Undetermined | TOTAL | | |
| H. C. & S. Co. | 6.0 | 1.4 | 14.4 | ... | —1.8 | 20.0 | 0.30 | 0.07 | 0.72 | ... | —0.09 | 1.00 | 2.01 | 0.43 | 4.79 | ... | —0.61 | 6.62 | 89.60 | H. C. & S. Co. |
| Oahu | 5.4 | 1.6 | 19.8 | 1.2 | —3.6 | 24.4 | 0.27 | 0.68 | 0.99 | 0.06 | —0.18 | 1.22 | 1.96 | 0.60 | 7.37 | 0.44 | —1.31 | 9.06 | 86.42 | Oahu |
| Ewa | 4.6 | 1.2 | 18.6 | ... | 1.8 | 26.2 | 0.23 | 0.06 | 0.93 | ... | 0.09 | 1.31 | 1.71 | 0.47 | 7.01 | ... | 0.67 | 9.86 | 85.21 | Ewa |
| Waialua | 9.6 | 2.4 | 19.6 | ... | 2.0 | 33.6 | 0.48 | 0.12 | 0.98 | ... | 0.10 | 1.68 | 3.34 | 0.86 | 6.84 | ... | 0.69 | 11.73 | 87.0 | Waialua |
| Maui Agr. | 6.6 | ... | 17.4 | ... | —1.8 | 22.2 | 0.33 | ... | 0.87 | ... | —0.09 | 1.11 | 2.17 | ... | 5.67 | ... | —0.60 | 7.24 | 87.80 | Maui Agr. |
| Pioneer | 6.8 | 1.0 | 19.2 | ... | 1.8 | 28.8 | 0.34 | 0.05 | 0.96 | ... | 0.09 | 1.44 | 2.38 | 0.36 | 6.74 | ... | 0.64 | 10.12 | 85.68 | Pioneer |
| Olaa | 8.6 | 2.8 | 22.6 | ... | 0.4 | 34.4 | 0.43 | 0.14 | 1.13 | ... | 0.02 | 1.72 | 3.44 | 1.14 | 9.14 | ... | 0.18 | 13.90 | 86.5 | Olaa |
| Lihue | 5.4 | 1.0 | 18.8 | ... | 2.2 | 27.4 | 0.27 | 0.05 | 0.94 | ... | 0.11 | 1.37 | 2.21 | 0.42 | 7.74 | ... | 0.94 | 11.31 | 83.8 | Lihue |
| Haw. Sug. | 5.8 | 0.8 | 17.8 | ... | —2.0 | 22.4 | 0.29 | 0.04 | 0.89 | ... | —0.10 | 1.12 | 2.00 | 0.28 | 6.12 | ... | —0.68 | 7.72 | 87.42 | Haw. Sug. |
| Honolulu | 8.4 | 1.0 | 20.8 | 0.2 | ... | ... | 0.42 | 0.05 | 1.04 | 0.01 | .... | .... | 3.09 | 0.35 | 7.60 | 0.10 | .... | ..... | 87.4 | Honolulu |
| Onomea | 4.2 | 0.4 | 17.6 | ... | 0.0 | 22.2 | 0.21 | 0.02 | 0.88 | ... | 0.00 | 1.11 | 1.90 | 0.16 | 7.84 | ... | 0.04 | 9.94 | 84.87 | Onomea |
| Kekaha | 5.8 | 1.2 | 20.6 | ... | 2.0 | 29.6 | 0.29 | 0.06 | 1.03 | ... | 0.10 | 1.48 | 2.14 | 0.43 | 7.53 | ... | 0.75 | 10.85 | 85.28 | Kekaha |
| Hilo | 4.6 | 0.8 | 15.2 | ... | 4.0 | 24.6 | 0.23 | 0.04 | 0.76 | ... | 0.20 | 1.23 | 1.92 | 0.34 | 6.49 | ... | 1.70 | 10.45 | 85.89 | Hilo |
| Haw. Agr. | 6.6 | 0.6 | 21.4 | ... | 1.4 | 30.0 | 0.33 | 0.03 | 1.07 | ... | 0.07 | 1.50 | 2.77 | 0.25 | 8.91 | ... | 0.61 | 12.54 | 85.94 | Haw. Agr. |
| Wailuku | 5.0 | 1.6 | 21.0 | ... | 0.0 | 27.6 | 0.25 | 0.08 | 1.05 | ... | 0.00 | 1.38 | 1.86 | 0.58 | 7.88 | ... | 0.01 | 10.33 | 86.5 | Wailuku |
| Makee | 9.4 | 1.2 | 24.6 | ... | 0.8 | 36.0 | 0.47 | 0.06 | 1.23 | ... | 0.04 | 1.80 | 4.26 | 0.57 | 11.09 | ... | 0.36 | 16.28 | 80.5 | Makee |
| Honokaa | 10.6 | 1.4 | 19.6 | ... | 0.8 | 32.4 | 0.53 | 0.07 | 0.98 | ... | 0.04 | 1.62 | 4.98 | 0.65 | 9.20 | ... | 0.35 | 15.18 | 83.34 | Honokaa |
| Hakalau | 3.4 | 0.4 | 16.0 | ... | —0.2 | 19.6 | 0.17 | 0.02 | 0.80 | ... | —0.01 | 0.98 | 1.43 | 0.15 | 6.91 | ... | —0.04 | 8.45 | 84.62 | Hakalau |
| McBryde | 9 8 | 1.4 | 19.6 | ... | —0.8 | 30.0 | 0.49 | 0.07 | 0.98 | ... | —0.04 | 1.50 | 3.64 | 0.52 | 7.32 | ... | —0.34 | 11.14 | 84.42 | McBryde |
| Laupahoehoe | 7.2 | 0.4 | 16.0 | ... | 4.2 | 27.8 | 0.36 | 0.02 | 0.80 | ... | 0.21 | 1.39 | 2.93 | 0.15 | 6.54 | ... | 1.74 | 11.36 | 86.60 | Laupahoehoe |
| Kahuku | 5.2 | 0.8 | 17.0 | ... | —3.2 | 19.8 | 0.26 | 0.04 | 0.85 | ... | —0.16 | 0.99 | 2.28 | 0.32 | 7.31 | ... | —1.37 | 8.54 | 82.91 | Kahuku |
| Hamakua | 9.0 | ... | 14.6 | ... | —0.4 | 23.2 | 0.45 | ... | 0.73 | ... | —0.02 | 1.16 | 3.76 | ... | 6.05 | ... | —0.14 | 9.67 | 85.72 | Hamakua |
| Pepeekeo | 5.6 | 0.4 | 15.8 | ... | 1.0 | 22.8 | 0 28 | 0.02 | 0.79 | ... | 0.05 | 1.14 | 2.28 | 0.19 | 6.55 | ... | 0.42 | 9.44 | 85.89 | Pepeekeo |
| Paauhau | 5.4 | 0.6 | 19.2 | ... | 2.2 | 27.4 | 0.27 | 0.03 | 0.96 | ... | 0.11 | 1.37 | 2.46 | 0.24 | 8.65 | ... | 1.00 | 12.35 | 84.21 | Paauhau |
| Koloa | 7.0 | 1.2 | 19.8 | ... | —2.8 | 25.2 | 0.35 | 0.06 | 0.99 | ... | —0.14 | 1.26 | 3.02 | 0.57 | 8.50 | ... | —1.20 | 10.89 | 83.3 | Koloa |
| Waiakea | 9.4 | 1.2 | 20.2 | ... | 4.6 | 35.4 | 0.47 | 0.06 | 1.01 | ... | 0.23 | 1.77 | 3.97 | 0.46 | 8.52 | ... | 1.97 | 14.92 | 83.93 | Waiakea |
| Hawi | 6.8 | 1.2 | 24.8 | ... | —0.2 | 32.6 | 0.34 | 0.06 | 1.24 | ... | —0.01 | 1.63 | 2.84 | 0.47 | 10.21 | ... | —0.05 | 13.47 | 83.31 | Hawi |
| Hutchinson | 7 6 | 0.4 | 18.4 | ... | 0.0 | 26.4 | 0.38 | 0.02 | 0.92 | ... | 0.00 | 1.32 | 2.85 | 0.19 | 6.96 | ... | 0.01 | 10.01 | 85.13 | Hutchinson |
| Honomu | 4.2 | 0.4 | 16.6 | ... | —0.4 | 20.8 | 0 21 | 0.02 | 0.83 | ... | —0.02 | 1.04 | 1.80 | 0.13 | 7.00 | ... | —0.14 | 8.79 | 85.69 | Honomu |
| Kaiwiki | 10.6 | 1.8 | 22.2 | ... | 0.4 | 35.0 | 0.53 | 0.09 | 1.11 | ... | 0.02 | 1.75 | 4.26 | 0.71 | 8.96 | ... | 0.13 | 14.06 | 85.30 | Kaiwiki |
| Waimanalo | 3 6 | 1.4 | 22.8 | ... | 1.0 | 28.8 | 0.18 | 0.07 | 1.14 | ... | 0.05 | 1.44 | 1.42 | 0.58 | 9.16 | ... | 0.38 | 11.54 | 81.55 | Waimanalo |
| Kohala | 6.8 | 1.4 | 19.6 | ... | 1.4 | 29.2 | 0.34 | 0.07 | 0.98 | ... | 0.07 | 1.46 | 2.85 | 0.62 | 8.29 | ... | 0.60 | 12.36 | 85.12 | Kohala |
| Kilauea | 8 2 | 3.6 | 25.6 | ... | 3.6 | 41.0 | 0.41 | 0.18 | 1.28 | ... | 0.18 | 2.05 | 4.30 | 1.87 | 13.55 | ... | 1.94 | 21.66 | 77.8 | Kilauea |
| Waianae | 8 4 | 2.4 | 21.6 | ... | 6.2 | 38.6 | 0.42 | 0.12 | 1.08 | ... | 0.31 | 1.93 | 3.00 | 0.83 | 7.70 | ... | 2.23 | 13.76 | 84.06 | Waianae |
| Kaeleku | 12.0 | 3.2 | 21.8 | ... | 4.6 | 41.6 | 0.60 | 0.16 | 1.09 | ... | 0.23 | 2.08 | 5.02 | 1.29 | 9.08 | ... | 1.94 | 17.33 | 83.54 | Kaeleku |
| Union Mill | 17.8 | 2 8 | ... | ... | 20.4 | 41.0 | 0.89 | 0.14 | ... | ... | 1.02 | 2.05 | 7.88 | 1.21 | .... | ... | 9.05 | 18.14 | 84.7 | Union Mill |
| Niulii | 14.0 | 2.8 | ... | ... | 23.8 | 40.6 | 0.70 | 0.14 | ... | ... | 1.19 | 2.03 | 6.85 | 1.41 | .... | ... | 11.64 | 19.90 | 80 77 | Niulii |
| Waimea | 7.2 | 1 2 | ... | ... | 39.4 | 47.8 | 0 36 | 0.06 | ... | ... | 1.97 | 2.39 | 2 62 | 0 43 | .... | ... | 14.55 | 17.60 | 85.54 | Waimea |
| Olowalu | 5.6 | 1 4 | 24.8 | ... | 11.4 | 43.2 | 0.28 | 0.07 | 1.24 | ... | 0.57 | 2.16 | 2.18 | 0.55 | 9.52 | ... | 4.37 | 16.62 | 81.89 | Olowalu |

# Sugar Prices

## 96° Centrifugals for the Period December 16, 1929 to March 15, 1930

| Date | Per Pound | Per Ton | Remarks |
|---|---|---|---|
| Dec. 16, 1929 | 3.865¢ | $77.30 | Porto Ricos, 3.86; Cubas, 3.87. |
| " 17 | 3.80 | 76.00 | Cubas. |
| " 19 | 3.77 | 75.40 | Cubas. |
| " 26 | 3.74 | 74.80 | Cubas. |
| " 27 | 3.77 | 75.40 | Cubas. |
| " 30 | 3.777 | 75.55 | Porto Ricos, 3.875; Philippines, 3.77. |
| " 31 | 3.80 | 76.00 | Porto Ricos. |
| Jan. 2, 1930 | 3.822 | 76.45 | Philippines, 3.815; Cubas, 3.83. |
| " 3 | 3.83 | 76.60 | Cubas. |
| " 4 | 3.80 | 76.00 | Cubas. |
| " 6 | 3.815 | 76.30 | Philippines, 3.80; Cubas, 3.80, 3.83; Porto Ricos, 3.80. |
| " 7 | 3.83 | 76.60 | Cubas. |
| " 8 | 3.80 | 76.00 | Porto Ricos. |
| " 10 | 3.796 | 75.93 | Cubas, 3.77, 3.83; Porto Ricos, 3.80, 3.785. |
| " 13 | 3.77 | 75.40 | Cubas. |
| " 16 | 3.815 | 76.30 | Porto Ricos, 3.80; Cubas, 3.83. |
| " 17 | 3.69 | 73.80 | Cubas, 3.71, 3.67. |
| " 18 | 3.655 | 73.10 | Philippines, 3.64; Porto Ricos, 3.67. |
| " 20 | 3.64 | 72.80 | Cubas. |
| " 21 | 3.61 | 72.20 | Cubas, Philippines. |
| " 22 | 3.595 | 71.90 | Porto Ricos, 3.58; Philippines, 3.61. |
| " 24 | 3.58 | 71.60 | Philippines. |
| " 28 | 3.61 | 72.20 | Philippines. |
| " 29 | 3.77 | 75.40 | Cubas. |
| " 30 | 3.716 | 74.33 | Porto Ricos, 3.67, 3.71; Cubas, 3.77. |
| Feb. 1 | 3.71 | 74.20 | Philippines. |
| " 3 | 3.64 | 72.80 | Porto Ricos. |
| " 4 | 3.675 | 73.50 | Porto Ricos, 3.58; Cubas, 3.77. |
| " 5 | 3.656 | 73.13 | Porto Ricos, 3.58; Philippines, 3.62; Cubas, 3.77. |
| " 6 | 3.64 | 72.80 | Porto Ricos. |
| " 11 | 3.61 | 72.20 | Porto Ricos. |
| " 14 | 3.55 | 71.00 | Philippines. |
| " 18 | 3.515 | 70.30 | Porto Ricos, 3.50; Philippines, 3.53. |
| " 19 | 3.565 | 71.30 | Porto Ricos, 3.55, 3.565, 3.58. |
| " 20 | 3.55 | 71.00 | Philippines, Porto Ricos. |
| " 25 | 3.565 | 71.30 | Porto Ricos, 3.55; Cubas, 3.58. |
| " 26 | 3.55 | 71.00 | Cubas. |
| " 27 | 3.485 | 69.70 | Philippines, 3.48; Cubas, 3.49. |
| " 28 | 3.52 | 70.40 | Porto Ricos. |
| Mar. 3 | 3.491 | 69.83 | Philippines, 3.52, 3.465, 3.49. |
| " 4 | 3.49 | 69.80 | Porto Ricos. |
| " 5 | 3.52 | 70.40 | Philippines, 3.49; Porto Ricos, 3.49, 3.55. |
| " 6 | 3.61 | 72.20 | Porto Ricos, Philippines. |
| " 7 | 3.625 | 72.50 | Cubas, 3.61; Philippines, 3.61, 3.64; Porto Ricos, 3.61. |
| " 8 | 3.67 | 73.40 | Cubas. |
| " 10 | 3.64 | 72.80 | Porto Ricos, 3.67; Philippines, 3.64; Cubas, 3.61. |
| " 11 | 3.61 | 72.20 | Philippines. |
| " 12 | 3.623 | 72.46 | Philippines, 3.64, 3.62; Porto Ricos, 3.61. |
| " 13 | 3.64 | 72.80 | Cubas. |
| " 14 | 3.66 | 73.20 | Porto Ricos, 3.67; Philippines, 3.65. |
| " 15 | 3.77 | 75.40 | Cubas. |